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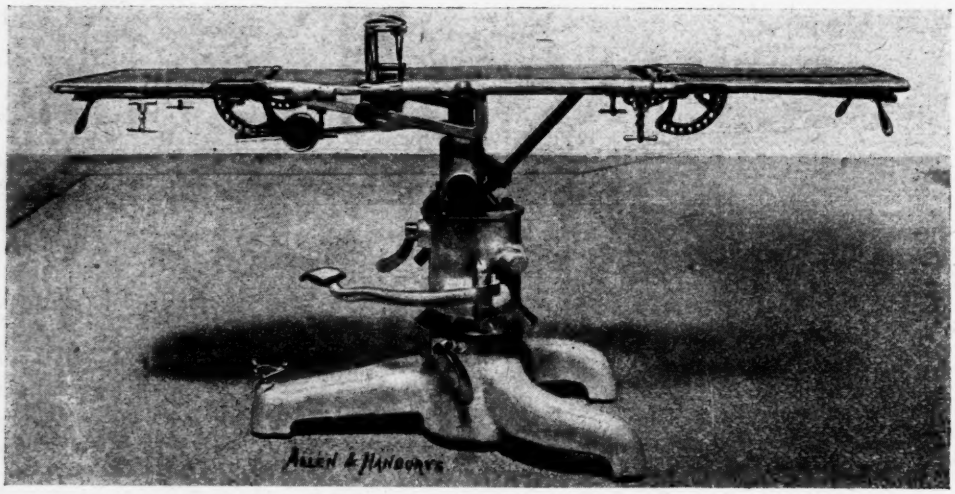

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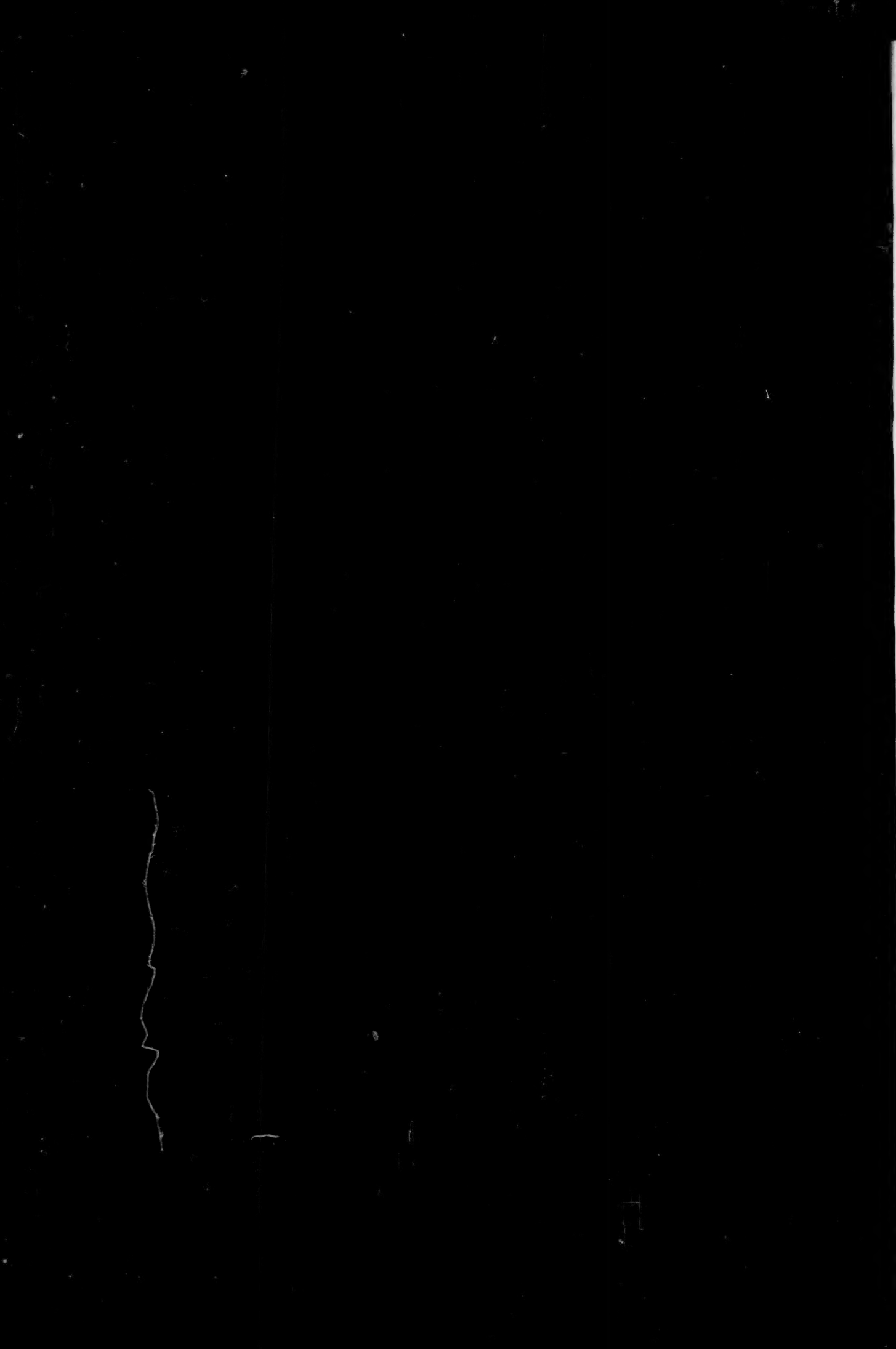

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THE
BRITISH JOURNAL OF SURGERY

INTRODUCTORY.

SURGICAL ORGANIZATION IN WAR.

AFTER a prolonged period of stagnation in the medical branch of the Army, a new impulse towards efficiency was derived from the energy and determination of Mr. Brodrick—now Lord Midleton—who followed along the path traced by the ever-memorable Lord Herbert of Lea.

When, on the formation by Lord Haldane of the Imperial General Staff, it became possible for the Medical Department of the War Office to adapt its administrative and executive work, in preparation for war, to a clearly-defined programme, a second great step had been taken in army medical organization.

We can discern three periods in the modern history of medicine in the army; three great war ministers are identified with reforms, the effects of which have been cumulative. There have been times when progress has been slow, when reform, if pressed at all, was pressed with more passion than discernment. If we are content to-day to blot out the remembrance of reactionary epochs, it is only because we are certain that the lessons of the present great war cannot be forgotten. Fundamental principles of sound administration have been vindicated, the basis of which may be held to be essential and indestructible. With the advent of the Imperial General Staff, then, adequate and systematic preparation for war became possible; the uneasy and timorous policy of indecision in military medical affairs, which so often marked the years between Lord Herbert and Lord Haldane, passed away for ever. A deliberate, considered, and definite plan was formulated; finicking considerations were set aside, and a real and earnest work succeeded the trivialities of the immediately preceding years.

The primary function of the Royal Army Medical Corps is the maintenance of the strength of armies in the field through prevention of disease. No other consideration is of equal magnitude or importance. Lord Herbert knew this. Parkes was the protagonist of the principle. Modern science by its discoveries has affirmed it over and over again. Yet, though its acceptance

as a cardinal principle of administration meant bayonets and money, it was not until the advent of Lord Haldane that the triumph of Army Sanitation was complete. Then began that study of technical problems of field sanitation which has meant so much; then, too, through systematic courses of instruction given to combatant officers and men, the Army generally became aware that practical measures for disease prevention rested on a sound scientific basis.

The collection, removal, distribution, and care of the sick and wounded constitute the second of the great functions of the Medical Service in war. Inasmuch as the conditions to be met are never precisely the same, it may be said to be often one of great difficulty and complexity.

On the opening of the present war, the medical branch of the Army was far advanced in its preparations. In addition to the Corps and the Nursing Service of the regular army, and their reserves, there existed an efficient Territorial Medical Corps, consisting of members of the civil medical profession, as well as a Nursing Service, both of which were capable of supplementing or replacing those of the regular army. Provision had been made to expand or to reinforce them *pari passu* with increases of the Army, and a Home Hospital Reserve had been formed. In the years which had elapsed since the South African War, the surgical equipment had been thoroughly overhauled, and was ready on mobilization. The general public, too, through the propaganda of the British Red Cross Society, had formed a supplementary organization destined to play a large part in all future wars; it is to-day fulfilling that destiny. It was difficult, indeed, to bring home to the public the necessity for preparation. The slow progress of the Voluntary Aid Detachment movement impeded for a prolonged period the consideration of matters of vital importance to the successful working of voluntary aid societies. We had, however, reached a stage in organization in which the rôle of the profession had been proclaimed and accepted. Thus, the public and the medical profession were prepared to assume their respective responsibilities for the care of the sick and wounded, and all that remained on the outbreak of war was the mobilization of the available resources. The Royal Army Medical Corps was no longer isolated. Even so, the strain upon the military medical system has been greater than anyone could have anticipated; for, owing to the sudden increase of the Army, mobilization and expansion had to proceed together. The services of the civil profession to the administration in this connection must never be forgotten.

Fully to set forth the magnitude of their task on the departure of the Expeditionary Force—henceforward it was no longer a question of the Royal Army Medical Corps—more space would be necessary than my limits allow. The internal organization of the medical units, the formation of the cadres for battalions, the establishment of hospitals at home and the formation of those for abroad; the provision of doctors, nurses, drugs, instruments,

dressings; the equipment of ships and trains, and the innumerable details associated with work of this kind, need only to be mentioned to be understood as offering opportunities for errors and omissions of far-reaching importance. But if to these is added the mass of work connected with the supervision of recruiting for the new armies, their housing, and the sanitation of camps and barracks, some idea will be gained of the scope and relation of Medicine to the art of war, and the part played by medical men will be realized.

Clearly, then, the essential feature of things as they existed, and as they exist to-day, is the burden of responsibility placed upon the shoulders of the medical profession. There was a time when these could not have been assumed; the nucleus of trained officers in so large an Army Medical Corps as we now possess would have been too small had the old conditions prevailed. We took the field with a larger number of experts in administration than we had ever before possessed. There were enough to complete the field units, and a sufficiency to leave the lines-of-communication units safe. The Home Hospital Reserve, which had been trained for some years, instantly assumed charge of the military hospitals at home, now emptied of their establishments. The administrative officers, matrons, and a sufficiency of men of the Territorial Force hospitals, had long been made aware, through annual practical courses of instruction in military hospitals, of the duties they would have to perform in time of war. It was only necessary to assemble round these the staffs for technical, medical, surgical, and nursing duties. It was not long before familiarity with their duties enabled the administrators, when required, to expand their hospitals and to form new hospitals as the force abroad increased.

As the medical profession is one and indivisible, regard was had to the relation of its members to their civil responsibilities. The interests of other government departments, local authorities, and civil hospitals had to be considered. The maintenance, too, of ordinary civil conditions with the least disturbance possible was an ever-present necessity, and added not a little to the task.

For the purposes of this paper, the foregoing statement may be said to embody all that it is necessary to premise as a preliminary to the study of the present. Such a study will enable those of us who care for these things to consider, when the time is opportune, the necessities of the future.

In war, the regular officers of the Medical Corps are compelled by circumstances to turn their attention and their energies to administrative matters, leaving to specially selected experts the technical work which the care of the sick and wounded involves. In all the formations of the Royal Army Medical Corps, therefore, room is made in the establishments for those of whom medical and surgical aid alone is required. But more than this is necessary, and nothing less than the almost complete transference of the responsibility

for the surgery of war to special officers can satisfy the conditions. Hence the appointment of Consulting Surgeons, by whom all subsequent surgical developments can be determined. They set the scope and the standard of practical work and scientific investigation. The Administration relies entirely upon them for the fixing of surgical policy. The responsibilities of these officers are great; their efficiency is proportional to their own appreciation of their powers. They determine whether the means at the disposal of the hospital surgeons are adequate or not. They supervise the operations and approve the operators, so that upon them depends whether or not all that is best in British surgery is available for the soldier. No official can afford to treat lightly representations made by them, and no commander would hesitate to accept their carefully considered verdict on any question submitted to them. These are great powers, but they are no greater than the importance of the subject requires. It is therefore through the consultants, and through them alone, that the maximum of surgical efficiency can be attained. They, and they only, can ensure a high standard of clinical and scientific work. The staffs of the hospitals in this campaign are drawn from numerous schools. Differences of practice and of opinion have consequently existed, discussions have been frequent, and authoritative pronouncements necessary. The onlooker may derive from many incidents the consoling reflection that if debates have been at times almost acrimonious, the friction of mind against mind has been productive of the best results.

Since I have not dwelt anywhere upon the existence of any limiting conditions within which efficiency must be confined, the reader will suppose there are none; and he will be right. The word 'red-tape,' which often falls so glibly from the mouths of men, themselves untrained in affairs and no better than mere technologists, is inapplicable to the surgical affairs of the Medical Corps. Each hospital is required and expected to establish its own standard of efficiency, and is subject only to the expert criticism of the professional advisers. In a word, the quality of the work rests with the consultants.

No one who has experience of the organization from the summit can fail to be impressed by the enthusiasm of its component parts. This enthusiasm is sometimes embarrassing, but it is never unreasonable. If it does not always limit its demands to what is possible, it constantly stimulates to the achievement of the apparently impossible. If we extend our view beyond the domain of surgery and its branches, we shall find that unforeseen contingencies have been well met by the suggestions of those best qualified to deal with them. Those in immediate contact with defects can best anticipate errors, and are best qualified to suggest the necessary action. Not infrequently those who sit in what are humorously described as 'high places' have been stimulated into activity by energetic assistants. This is as it should be: the administrator is the servant of the executive. In the last two years, free play has

been given to the imagination of many who would make the future better than the present. Consequently, new branches of work have been organized to meet special conditions, and there has been a division of labour to meet the constantly increasing new movements. It must not be supposed, however, that the standard of excellence which the profession has set up is universal. There are very distinct differences between one area and another. If full freedom of action is allowed to groups of units, the personal equation quickly leads to noticeable differences, for it is not always fully appreciated how much liberty is possible, and failure to grasp situations sometimes delays efficiency. But the enthusiasm is the same everywhere, and the search for improvement never relaxed.

The nature and characteristics of the wounds received in this campaign have profoundly influenced the surgical practice of the hospitals. A corresponding demand has been made upon surgeons to solve the new problems which have arisen. The campaign was entered upon with a fully justifiable belief that our recent experiences of military surgery rendered us specially proficient in the treatment of gunshot wounds; but we were deceived. I shall not readily forget the anxiety of the early days of the war, when it became apparent that we were confronted with old problems of military surgery which required investigation in the light of newer knowledge, or how, when the bacteriologist, the surgeon, and the physician found common ground, opinions inevitably clashed. We can remember periods of excitement, when dogmatic assertions as to this or that method of procedure seemed to indicate that, after all, we were not so very far removed from the age of empiricism. At this juncture the National Research Committee gave to the Army aid which has proved invaluable in the settlement of a host of questions which have arisen. From that time onward laboratory after laboratory has been established at home and abroad, so that, in the sequel, all science was pressed into the service of the Army. It was not long before differences of opinion were reconciled, and, as nearly as may be, ground of agreement on burning questions was found. It is fair to say that medicine in war has never had so fully the benefit of organized scientific researches. The treatment of wounds, and, above all things, the treatment of fractures, the after-treatment of surgical cases, including the use of massage, electrotherapy, baths, and so on, have thus each developed under the representations of experts. We have had our share of unwise and impracticable proposals; but educated opinion has guided us amidst a host of difficulties, and has helped us to steer clear of the too-enthusiastic expert. One is tempted here to consider specifically how far the application of science has enabled us to deal with problems never before attempted in the Army; and although this is impossible at present, we may at least note that wherever a difficulty has arisen, whether it was one connected with epidemic disease or one relating to some surgical question, we were able,

on every occasion, to fall back upon the workers in the laboratories and in the wards for guidance. How much has been done by the National Research Committee at home, and by laboratory workers abroad, will appear hereafter. Let it now suffice to say that none of our administrative measures were experiments : we have not had, as in the past, to seek for light blindly, or to depend upon clever guess-work. Numerous instances might be adduced to show that, under the guidance of scientific men, we were able to administer strictly in consonance with scientific suggestions. This dependence upon science is, in my opinion, one of the features of the war, but it must be left to the historian to deal with.

Looking back upon almost two years of work, and reflecting upon such merits and defects of medical organization for war as may strike us, each of us is entitled to draw conclusions, both as to the adequacy of the initial preparations, and the manner in which the development has proceeded. We must be careful, however, to consider only those matters which lie within our own province. It is not edifying, and is calculated to detract considerably from the reputation which the medical profession has earned as a business body, to find some of its members expounding things for the understanding of which a special education is required and which mainly concern the General Staff. Yet this is a spectacle frequently presented to us. What are called 'medical arrangements' in an army or armies are made up of the combined efforts of several branches, and the organization as a whole is defined by another profession. Those parts which for their proper construction and management require special technical knowledge, are those which alone concern us : technical knowledge of disease-prevention, of the management of epidemics, of food values, of the investigation and treatment of disease and injuries, of hospital management, of recruiting and invaliding. These are the questions which affect us, and they tax the resources of our profession. The constitution of armies must be left to those whose business it is to study this very difficult subject.

The surgeon is especially interested in the collection, removal, and hospitalization of the wounded, and in the provision of appliances. He has never, hitherto, been the predominant partner in war work. He has sprung into prominence, partly because the war is on so great a scale, and partly because of the actual and relative diminution of disease. He has had to give care and thought to affairs which in civil life scarcely concern him. It is little appreciated how great has been his share in perfecting the organization itself, and how largely the administrators have had to rely upon him for the prevention of errors. If we speak of the care of the wounded in the hospitals as reflecting the highest credit on the profession, we do not mean to emphasize the skill of the operators, their careful selection, or the adequacy

of the equipment only, but that the whole story of the wounded man, whether destined to return to civil life or to the ranks, tells of a finished piece of surgical procedure, complete in all its details, through the efforts of the surgeon. He has displayed a faculty for invention to meet unusual conditions, as, for example, in connection with immobilizing apparatus, which has robbed transport—always a difficult thing—of all its terrors. We see evidence of his work from front to base; and his work in command depots is of no small importance. If surgery is the outstanding necessity of the humanitarian work of the war, it must be admitted that the surgeon has risen to the occasion, and displayed to us the methods and the means of establishing an all-round good surgical system.

If we cast our regards around us, we find a tendency more and more to classify the wounded into groups, demanding experts in special branches of knowledge for each class. This is inevitable, and is suggestive of changes in the future. The system has not been in the first place designed, nor established of set purpose. It has evolved, and the advantages have been so apparent that it has been encouraged. It has reached its highest development, perhaps, at Aldershot. Since we never cease to be students, its educative value is enormous, and it offers unique opportunities for research. Unlike many other tendencies, there are no administrative objections to it, and it can be suffered to grow and flourish without the production of a narrow specialism.

In the direction of orthopædics there has been a very conspicuous differentiation of surgical work, in the formation of special institutions and command depots, as well as, to a great extent, in the convalescent hospitals at Eastbourne and elsewhere. This has arisen out of the necessities of the case; but there is more than this to be said about it. The management of the classes which we have been obliged to recognize as orthopædic is of pressing importance, and nothing has been more noticeable than the initial unpreparedness of the profession to deal with them. Nothing, too, has given cause for greater anxiety than the whole group of questions which circle round orthopædics. There is a duty to the State and to the soldier himself which lends special importance to the subject. To-day the surgeon is busily engaged in the settlement of the many problems which arise. Indeed, the subject is of great public importance.

The pages of the professional journals afford abundant proof of scientific activity in almost every branch of our profession, but since remarks on the whole series of phenomena presented to us are out of place in a surgical journal, they must be left unnoticed.

If some of the developments to which I have briefly alluded have been found to be necessary to the proper care of the wounded in war, and if the logic of events has obliged us to display a tendency to specialization of work,

it can only be because the necessity of some such process has been forced upon us. The truth is that without it full efficiency cannot be attained, and I am myself convinced that the more the organization of hospitals into special departments is pursued, the greater will be the degree of efficiency reached. It would appear to be the case that, in seeking to avoid a narrow specialism in hospital organization, we have failed in our profession to establish sufficient differentiation of functions, and that we demand from the general surgeon a more extensive knowledge than he can nowadays possess. Experience has shown, and continues to show, that in such departments research is encouraged, and knowledge acquired and diffused more readily than could otherwise have been the case. One cannot avoid an uncomfortable feeling that if hospitals in civil life had been organized on such a plan, a higher efficiency would have been manifest at the outset.

It is obviously impossible for me to allow myself the luxury of speculating on the future of the military medical organization, however tempting is such a task. But we may ask ourselves, for example, being wise after the event, whether a homogeneous profession should not have one military medical organization only to fall back upon in time of war, and not several organizations with different conditions of service and varying responsibilities; or whether the profession will, for the better settlement of these questions in the future, devote more consideration than it has hitherto given to its relation to the public and to public departments; for everything depends upon this.

These and other questions must be settled by younger men; it is not for us to provide for a future in which we can play no part. There are now men working under conditions set up by those who have preceded them, estimating their value, or their worthlessness, as the case may be, and resolved, when their time comes, to construct after their own ideas. It is for them to fashion the future. But if the organization of the profession is to be undertaken, it can only be by men educated to the task, and not trained merely as technologists. Herein lies the responsibility of the medical faculties of the universities and of the medical schools. The rising generation should not be obliged to burrow their way to the light as have their predecessors. The most that we can claim is that we have shown the way.

ALFRED KEOGH.

SIR CHARLES BENT BALL., Bart.

In Memoriam.

SIR CHARLES BENT BALL,

Baronet, Knight Bachelor, M.D., M.Ch., Univ. Dubl., F.R.C.S.I.;
Regius Professor of Surgery in the University of Dublin;
Honorary Surgeon to His Majesty the King in Ireland;
Representative of the University of Dublin on the General Medical Council.

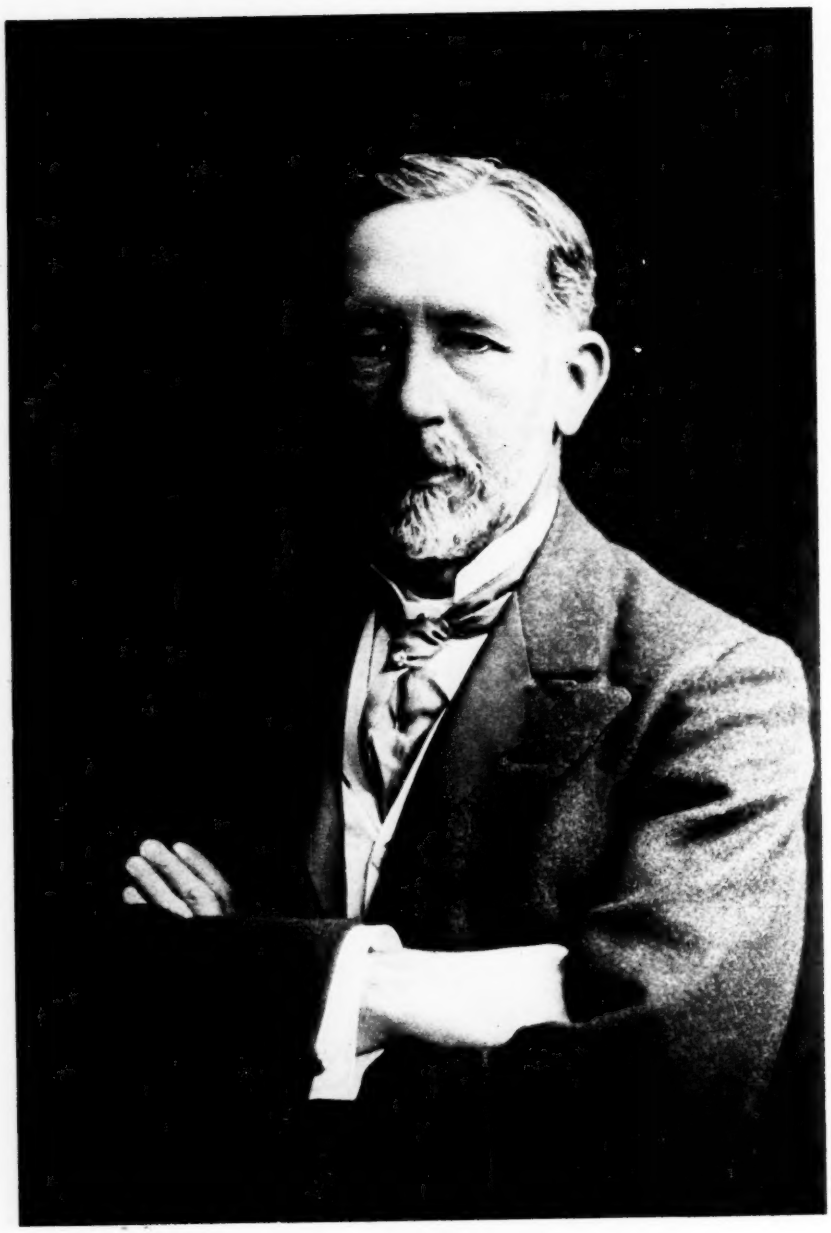
We record in the present number, with deep regret, the death on St. Patrick's Day, March 17, 1916, of Sir Charles Bent Ball, the distinguished Dublin surgeon. He had just entered his sixty-sixth year, having been born in Dublin on February 21, 1851. He was a member of the Editorial Committee of this Journal since its foundation in 1913. The manner in which Sir Charles Ball gained his great surgical weight and influence is an example of the steady climb of the scientific ladder of surgical fame. He was educated at Trinity College, Dublin, graduating in Arts in 1871, and demonstrated his great aptitude for science by obtaining a Senior Moderatorship and Gold Medal in Biology. By 1872 a Medical Scholarship, a Travelling Prize, and nearly all the available prizes of the medical school had fallen to this already distinguished pupil. Before commencing practice he studied in Vienna in the year 1873.

In his early days he was surgeon to a colliery and ironworks in Monmouthshire. He was destined, however, for greater things, and after six years he commenced as a Dublin surgeon the career which was attended with such success. Trinity College, having already recognized his ability, appointed him on the staff of the School of Physic. His appointment as University Anatomist soon followed, and on the death of Sir George Porter in 1895 he obtained the high distinction of being chosen as Regius Professor of Surgery in the University of Dublin. He was a Fellow of the Royal College of Surgeons in Ireland, and in 1900 was elected, together with the late Professor E. H. Bennett, a Fellow of the English College *honoris causa*. In 1906 he was chosen to represent Dublin University on the General Medical Council; his services in this capacity cannot be overestimated. The Council did him the honour of electing him chairman of the Examination Committee, and also one of the two representatives for Ireland on the executive committee of that body. He received the honour of knighthood in 1903, and in 1911 he was created a baronet of the United Kingdom. Ball was Honorary Surgeon to the King in Ireland, and on the outbreak of war was appointed Consulting Surgeon to the troops in Ireland, with the rank of Lieutenant-Colonel in the Royal Army Medical Corps.

Throughout his life he retained his love of natural science, and acted as President of the Royal Zoological Society of Ireland during the past five years.

He contributed largely to the literature of surgery. His work on the rectum and anus brought credit to the Dublin school, and is the standard book of reference all over the world. His operation for the radical cure of hernia by torsion of the sac had many advocates. He wrote on cases of *Patent Urachus*, on *Varicocele Nævus*, and *Varicose Veins of the Leg*, on *Myxoma of the Bladder*, on *The Treatment of non-malignant Gastric Ulcer*, and recently on *The Relief of Ascites by Veno-venostomy*. In this latter paper Ball described how he passed a sinus forceps from the abdomen into the thigh through the femoral canal, and thus brought the divided saphenous vein into the pelvic sub-peritoneal tissue; a sigmoid vein was isolated for about an inch, was then divided, and anastomosed end-to-end with the saphenous vein; blood was seen to flow without leakage from the sigmoid vein into the saphenous vein; the patient made an excellent immediate recovery with no return of the ascites. In 1902 he delivered the Lane Lectures in San Francisco, and in 1903 he was the Erasmus Wilson Lecturer at the Royal College of Surgeons in England.

Sir Charles was a man of strong personality; he believed in success obtained by scientific merit; he taught his students to base their work on strong foundations of knowledge; he despised any approach to charlatanism or advertisement; and thus his memory is reverenced by his professional colleagues and pupils in the school which he so much adorned.



ARTHUR EDWARD JAMES BARKER

ARTHUR EDWARD JAMES BARKER.

F.R.C.S. (England and Ireland).
Professor of Surgery, University College Hospital Medical School.
Consulting Surgeon to Queen Alexandra's Military Hospital, Millbank.
Surgeon to Out-Patients, King Edward VII. Hospital for Officers.
Colonel, Army Medical Service.

It is with much regret that we chronicle the death of Colonel A. E. J. Barker, A.M.S., a distinguished member of the Editorial Committee of this Journal, which occurred at Salonika on April 8, 1916. Early in the war Mr. Barker had been appointed Consulting Surgeon to the Southern Command, later he went to Malta, and was transferred to Salonika where it was his death, which resulted from acute pneumonia and nephritis.

In the short notice we can only deal very briefly with some of the aspects of Colonel Barker's surgical work, the chief portion of which was carried out at University College Hospital, where he was successively surgical registrar (1898–1903), assistant surgeon (1903–1907), and surgeon (1907–1915). Forty years' living with surgery has made many changes, in most of which Barker took a very prominent part. His work, moreover, and the whole of his career was characterized by a keen interest in detail, a really striking degree of accuracy in observation, a very extensive knowledge of the literature of any subject which he took up, and a very great capacity for original thought. In the latter connexion his thorough knowledge of Continental methods and writings always helped his work, sometimes to his own work, and many instances could be given in which Barker was instrumental in popularizing and developing [illegible] methods of surgical work in this country.

His interest in the subject of the [illegible] strongly developed at an early stage of his career, and in his own hospital he took no small part in the gradual modification and simplification of the earlier Listerian methods, which have gradually resulted in the present more strictly aseptic system. Even in the early eighties Barker was treating his ordinary operation wounds with simple dressings of salicylic wool, applied with uniform pressure so as to limit the amount of oozing and serous exudation from the tissues, and thus preventing the use of drainage tubes unnecessary even in extensive operations. Every possible detail in the antiseptic system was studied by him with a care which gave to all who worked with him an appreciation. A valuable lecture on [illegible] to the Medical Staff of Surgeons and Assistants in Operations" (*Lancet*, April 15, 1905) bears evidence of the careful thought which he bestowed on even details in the treatment of wounds. Barker was an believer, and of the first in this country to wear rubber gloves in operating, although later he [illegible] considerable [illegible] discarded them, except as a protection in dealing with septic cases. He was also among the first to operate in a sterilized overall, and to cover the [illegible] mouth with a gauze mask. He made a very careful study of the [illegible] ligature and suture materials, and for many years [illegible] used almost [illegible]

ordinary linen thread sterilized by boiling. It was in abdominal surgery that Barker especially excelled, and in procedures requiring delicate manipulation and accurate suturing he was particularly successful. In his earlier days he had devoted much attention to the operations devised for the radical cure of hernia, at a time when this branch of surgery was in its infancy. His work in this subject was followed by numerous communications on the surgery of the abdominal viscera, including such subjects as acute intussusception, gastro-enterostomy, enterectomy for gangrenous hernia and other conditions, and acute pancreatitis.

It is just thirty years ago (Jan. 5, 1886) that Barker performed the first successful gastro-enterostomy in this country—a success which must not be regarded in any way as a merely fortunate accident, but rather the result of a most carefully planned and elaborated procedure. At that time the operation, designed and performed by Woelfler in 1881, and undertaken about twenty times abroad, had only been performed in this country by Reeves at the London Hospital, but without success. The subject of Barker's operation was a woman, age 37, suffering from carcinoma of the pylorus; she survived the operation for fifty-three weeks, being completely relieved of the symptoms of pyloric obstruction. Barker performed the anterior operation, and adapted an important modification of Woelfler's method, suturing together the seromuscular coats of the stomach and jejunum before incising the mucous membrane of either. It is interesting to note that the troublesome vomiting which followed the operation was relieved after placing the patient in the semi-recumbent position.

No stronger evidence of the strides which abdominal surgery has made in the last thirty years could be found than in comparing the space afforded to the subject in Barker's *Manual of Surgical Operations*, published in 1887, with that which it occupies in similar works at the present time.

In other departments of surgery, Barker also did valuable pioneer work. Particularly we would refer to that in connection with tuberculous diseases of bones and joints. This subject was brought forward in his Hunterian Lectures, in several articles in Holmes's and Treves's Systems of Surgery, and in numerous other communications. His papers on excision of the hip-joint for tuberculous disease, read before the Royal Medical and Chirurgical Society of London, in 1888 and 1890, drew prominent attention to this important subject, and led to much discussion. The main object of these communications was to show that, with careful treatment of the abscess cavity by scraping and hot water flushing, primary union without suppuration and without the necessity of drainage could be secured in a considerable proportion of cases. Since that date the treatment of tuberculous joint disease, especially in children, has gradually come to be carried out on more conservative lines; nevertheless, Barker's work in this direction, as well as in the treatment of spinal abscesses, must remain as important advances in the subject.

In 1890 Barker chose for the subject of his Hunterian Lectures the treatment of certain intracranial inflammations, chiefly those occurring as complications of chronic suppuration in the middle ear. His experience in this branch of surgery had been gained chiefly whilst in charge of the Ear Department in University College Hospital. The lectures contained much

practical information, especially with regard to the operative procedures required for suppuration in the mastoid antrum and for cerebral abscesses and other intracranial suppurations.

During many years before his death Barker had devoted much time and untiring labour to the whole subject of local and regional anæsthesia, and we feel sure that it will be generally admitted he had done more than anyone else in this country to develop and systematize the methods employed. Among his most important communications on this subject may be mentioned that on "Local Analgesia," published in *the Journal of the Royal Army Medical Corps* in August, 1907; a translation of "Observations on the Sensibility of the Abdominal Cavity," by Professor Lennander, of Upsala; and, lastly, "Reports on Spinal Analgesia," published in the *British Medical Journal* in 1907 and 1908. Barker's work on spinal analgesia commenced with a careful study of the writings of Bier, Tuffier, and others; then with characteristic energy he set himself to work out the method on his own lines, testing one by one every detail until a very uniform degree of success was ensured. As to the physical characters of the fluid used for the injection, Barker came to the conclusion, "that if we are to aim at localizing our spinal analgesia to any particular region of the cord, we ought to employ the force of *gravity* acting upon an injected compound of greater density than that of the liquor spinalis." This increased density he obtained, not by an increased percentage of NaCl, as others had done, but by using a solution of stovaine containing 5 per cent of glucose. The exact position of the patient's body during the injection was carefully studied, and a special syringe and needle were devised, which are now very extensively employed. The mode of appearance of the analgesia, and its duration, were accurately recorded in a long series of cases, and directions were given for the prevention and relief of the occasional unpleasant after-effects. Among the many practical details necessary in order to ensure success was mentioned the use of a separate sterilizer for the syringe, lest the presence of even a trace of alkali should destroy the stovaine.

We have referred somewhat fully to Barker's work in spinal analgesia, because we are convinced that the profession in this country is deeply indebted to him for the share which he took in promoting the subject, and for recording his work with sufficient detail to enable others to practise the method with a great measure of success. Barker remained a student to the end; and when last year he retired from the active staff of University College Hospital, it was difficult to realize that he had attained the age of sixty-five years.

TETANUS.

By C. H. BROWNING, London.

Director of the Bland-Sutton Institute of Pathology of the Middlesex Hospital.

The occurrence of muscular spasm following a wound was recognized by the physicians of antiquity, and Aretæus emphasized the gravity of the prognosis in such cases. The comparative rarity of the disease, however, prevented it from attracting wide attention, and extended observations do not appear to have been made until the opportunity was afforded by the wars of the eighteenth century, with their high number of casualties, which included many cases of tetanus. As will be seen later, even provided that the terrain is suitable, it is only war that affords any considerable number of wounds favourable for the implantation of tetanus; though the employment of fireworks on a large scale, as in the fourth of July celebrations in the United States of America, has led to very similar conditions and has been productive of many cases.

To-day, knowledge with regard to the pathogenesis of tetanus is fairly complete, and consequently great advances in therapy, and especially in prophylactic measures, have been made. These all date from the commencement of the bacteriological epoch in the last quarter of the nineteenth century, and are directly due to the employment of animal experiment in the elucidation of disease. Thus, two Italian observers, Carle and Rattone, undeterred by the previous failures of other workers, succeeded in 1884 in producing tetanic symptoms in rabbits, which they inoculated with an emulsion of tissue from the neighbourhood of an acne pustule in a case of tetanus; further, they transmitted the disease by transference from one animal to another. Nicolaier, in 1885, showed that inoculation of mice and other animals with samples of earth caused tetanic symptoms, and he recognized the probable causal agent in a slender bacillus which he grew in mixed culture with other organisms on blood-serum. In 1889, Kitasato obtained pure cultures of Nicolaier's organism under anaerobic conditions; he grew mixed cultures, and then heated these at 80° C. for one hour, by which means the other organisms were killed; the tetanus bacilli, which form resistant spores, survived the heating, and happening to be the only sporing organisms present, they were then obtained as a pure growth when cultures were subsequently incubated in an atmosphere of hydrogen. It was found that although the tetanus bacillus is comparatively uncharacteristic in the unspored stage (a Gram-staining filamentous organism of variable length, which possesses flagella and in the living state is motile), a highly distinctive appearance is presented when spores are fully developed. Each bacillus then possesses one large, perfectly terminal spore, practically spherical in outline, so that the descriptive term 'drumstick bacillus' is extremely appropriate. It must

be remembered, however, that tetanus bacilli cannot be recognized with certainty in pathological material, such as the secretions from wounds, by microscopical examination alone; this point will be referred to in detail later.

As regards the manner in which the disease-effects are produced, Knud Faber, in 1889, produced tetanic symptoms by the injection of bacterium-free filtrates of impure fluid cultures of *B. tetani* mixed with other organisms; he showed that, as in the case of diphtheria toxin, the filtrates were deprived of their toxic power by heating at 65° C. Kitasato then completed the proof by demonstrating the presence of toxin in sterile filtrates from pure cultures of *B. tetani*.

Under suitable conditions *B. tetani*, when growing in fluid medium, produces one of the most potent soluble poisons known, for a wide variety of animals; thus, the horse, which is exceedingly susceptible, but probably not more than man, can be killed by a subcutaneous injection of 0·003 c.c. of concentrated toxin. In 1890, Behring and Kitasato showed that when an animal was injected with repeated doses of tetanus toxin in non-lethal amounts, it gradually acquired marked tolerance to the poison; in addition, the blood-serum of such an actively immunized animal neutralized tetanus toxin when mixed with it *in vitro*. The mixture of many times the fatal dose of tetanus toxin with a suitable amount of such 'antitoxic' immune serum proved quite harmless when injected into a susceptible animal. This observation constitutes the basis of serum therapy.

In what follows, no attempt is made to deal equally fully with tetanus in all its aspects; but special attention is devoted to those observations, both clinical and experimental, which have a direct bearing on the prophylaxis and treatment of the disease; every effort has been made to avoid omission of any important fact, especially in the light of recent experience, but only representative works have been quoted from the literature.

PATHOGENESIS.

Source of Infection.—Tetanus bacilli or their spores are so widely distributed on the earth's surface as to be almost ubiquitous; but they are especially numerous in the dust of roads, in gardens and highly cultivated arable land, and in horse and cattle manure. They have been repeatedly demonstrated in the intestinal contents of horses and cattle, and even of men, especially those working in stables or with horses. Noble found that out of four horses in one stable, which were examined over a period of six months, one showed the presence of *B. tetani* in cultures made from 0·1 gram of fæces during the first three months, the results thereafter, even with 1 gram of fæces, being negative; a second horse gave positive results with 1 gram in three tests during the first fourteen days, but not again; the other two remained negative throughout. This author therefore concludes that certain horses afford a more favourable habitat for the tetanus bacillus than others, and that in suitable animals multiplication of the organism must occur in the intestine, in order to explain the continued excretion of bacilli; hence these animals are tetanus 'carriers.' Whether intestinal multiplication is the whole explanation of the prevalence of tetanus bacilli is not clear; but it is

certain that the presence of these organisms in horses is variable, since Lukas obtained 16 positive results among 17 horses, while McLeod, Soga, and Roger in this country (unpublished) obtained only 1 positive out of upwards of 30 horses (half of these animals were at a knackery, the others were farm horses working in the neighbourhood of London). Römer found tetanus antitoxin constantly present in the blood-serum of cattle which were over two years old, and as the presence of *B. tetani* in the intestinal contents has been proved by the inoculation of mice with fæcal cultures, he considers that adult cattle are, as a rule, the subjects of latent infection with *B. tetani*.

Manure and highly manured soil are therefore pre-eminently the sources of infection with B. tetani (and also of the other potentially pathogenic anaerobes, the malignant œdema bacillus, *B. Welchii*, etc.); but whether the organism flourishes exclusively, or even mainly, inside or outside the animal body, is not yet settled. Owing to the resistant character of the spores, infected material may under ordinary conditions continue to be a source of danger for an almost indefinite period except when exposed to direct sunlight.

A wide variety of objects contaminated with tetanus spores have acted as the vehicles of infection, such as splinters of wood, portions of clothing and other foreign bodies, felt used to pad a plaster jacket (Kirmisson), plant fibre—pengawar djambi—employed as a dressing for wounds (Jacobsthal), vaccines, diphtheria antitoxin, and possibly catgut and vaccine lymph. Contaminated material employed to dress the stump of the umbilical cord appears to explain the heavy incidence of tetanus neonatorum in certain parts of the world, especially in the tropics. With reference to the production of tetanus by antidiphtheritic serum, it is to be observed that tetanus toxin may be present in the blood of horses some days before they manifest symptoms; hence harmful effects may follow the administration of a serum which is culturally sterile. Nowadays, precautions are taken to determine that antisera are free from tetanus spores or toxin by injecting a large amount—10 c.c.—into several guinea-pigs, and also by cultural tests; but, of course, it is possible that the serum may become infected in the course of bottling, after it has been tested.

It is of practical importance to know what procedures will sterilize articles infected with tetanus spores. Thus, Kitasato found steam at atmospheric pressure (i.e., 97·5°–98° C.) killed these spores in five minutes (this contrasts with the spores of malignant œdema, which survive heating for an hour under similar conditions); 5 per cent carbolic acid required fifteen hours to kill; 5 per cent carbolic acid + 0·5 per cent hydrochloric acid required two hours; 1–1000 corrosive sublimate required three hours; 1–1000 corrosive sublimate + 0·5 per cent hydrochloric acid required half an hour.

Conditions of Infection.—The tetanus bacillus and its products are essential for the occurrence of the disease, the characteristic symptoms being due to absorption of the specific soluble toxins which it produces. *B. tetani*, however, is probably quite incapable of obtaining a foothold in the living tissues by its own unaided action. The circumstances which enable it to proliferate in the body under natural conditions are, as a rule, those which promote sepsis,—that is to say, a wound contaminated with pyogenic organisms. Further favouring conditions are present where the wound is deep,

penetrating—so as not to drain spontaneously—and where foreign matter of any kind is embedded in the tissues. The presence of much necrotic tissue seems to aid the growth of *B. tetani*; accordingly, lacerated contused wounds are specially liable to be affected; these conditions, of course, also tend to produce sepsis, and so they exert a double action in favouring the onset of tetanus.

Various workers have shown that living tetanus spores, freed from toxin by heating at 80° C., produce no harmful effect when injected subcutaneously into animals; they settle at the site of injection, but some are transported throughout the body, and remain alive for a considerable time in various organs, e.g., the liver. Vaillard and Vincent found that such detoxicated tetanus spores, when injected subcutaneously, were actively taken up by phagocytes; hence it is probable that these cells are responsible for the transport of the spores. The spores remain alive, and under favourable conditions are capable of germinating, and by giving rise to toxin may produce fatal tetanus. In guinea-pigs, subsequent injection of living staphylococci into the site at which the spores were introduced, at any time up to one month later, regularly lights up tetanus (Francis). Tarozzi caused tetanus to develop in a rabbit six weeks after the intravenous injection of heated spores, by producing simple fracture of the femur. Semple found viable, virulent tetanus spores at the site of inoculation, six months after subcutaneous injection into guinea-pigs.

Quinine has the same effect as have staphylococci in lighting up a latent tetanus infection,* and in this way Semple explained cases of tetanus in men following subcutaneous injections of this drug made presumably with aseptic precautions. He advanced the hypothesis that spores which had by some means entered the tissues at a previous date were enabled to proliferate at the site of the injection of quinine owing to the resulting tissue damage.

The fact that under ordinary conditions of artificial culture *B. tetani* is a strict anaerobe, seems to have obscured somewhat the view of the pathology of the disease, the idea being prevalent that conditions strictly comparable with an anaerobic culture apparatus require to be arranged in the tissues before *B. tetani* will flourish. This has been dispelled by recent work, since even in artificial cultures the organism will grow in bouillon if the minced pieces of flesh are left in the broth, although no growth is likely to occur if a clear filtered specimen of the same broth be employed; as Tarozzi and Theobald Smith first demonstrated, solid tissue particles promote growth. Again, mixed infection with staphylococci favours the proliferation of *B. tetani* in the tissues, though not *in vitro*, and a number of other organisms exert a similar favouring action. Whether other anaerobes, like Welch's bacillus and the bacillus of malignant œdema, specially assist *B. tetani* in the tissues is not clear; these organisms are usually present in wounds contaminated with 'rich' soil, and, as has been seen, their habitat is the same as that of *B. tetani*. As the present war has shown, shrapnel and grenade

* It is interesting to note that the favouring agencies vary to some extent with the species of animal investigated; thus staphylococci activate latent tetanus infection in mice, while quinine fails to do so.

wounds afford the combination of conditions specially favourable for tetanus, but a variety of other lesions have led to the disease, such as burns and frost-bite. Although the importance of marked sepsis in the causation of tetanus can scarcely be exaggerated, it must be remembered, on the other hand, that numerous instances have been recorded in which the site of infection was an otherwise trivial wound, which had healed perfectly before the onset of tetanic symptoms; sometimes, but by no means invariably, foreign bodies have been found in the cicatrices. Thus it comes about that there are no clinical features of a wound pathognomonic of tetanus infection. Tetanus has also been observed to follow injuries unaccompanied by solution of continuity of the integuments, e.g., in cases of simple fracture, hæmatoma, etc. (see Natonek). Accordingly, the presence of aseptic necrotic tissue or trauma, apart from mixed infection, has been considered to afford conditions suitable for the germination of tetanus bacilli, as in the classical work of Kitasato, who produced tetanus in monkeys by introducing subcutaneously splinters of wood impregnated with tetanus spores; it appears, however, that in most experiments of this kind other organisms also are found at the site of inoculation.

The site of wounds which give rise to tetanus is most commonly on the limbs, first on the legs, then on the arms; the rarity of tetanus complicating wounds of the thorax was noted in the American Civil War. Other paths of entry of the tetanus bacillus apart from wounds have been proved, such as the tonsils and carious teeth, and in one case *B. tetani* was shown by animal inoculation to be present in an abscess of the lung in a young man who died of tetanus when convalescent from pneumonia; also the genital tract affords entrance to the bacillus in women who develop tetanus shortly after parturition. Although, as Ransom showed in guinea-pigs, the healthy alimentary tract has little tendency to absorb tetanus toxin, even when administered in such large amounts that it can be detected in the fæces, it is probable that intestinal lesions, caused by organisms or otherwise, may afford a foot-hold to *B. tetani*; the complication of typhoid fever with tetanus observed in the wars at the beginning of the nineteenth century is probably to be explained in this way. There remains, however, a certain proportion of 'idiopathic' or 'rheumatic' cases, said to be most frequent in children and of relatively good prognosis ('pseudotetanus' of children—Pexa), in which no site of entry of the organism can be determined. In some of these the disease has supervened after exposure to cold or wet, so suggesting that depression of vitality has enabled the bacillus to proliferate and form toxin (in this connection it is noteworthy that Larrey concluded on clinical grounds that exposure to cold and wet favoured the outbreak of tetanus after war wounds); but in others no favouring circumstance could be held responsible for the attack. Whether auto-infection in the sense of absorption of spores from the alimentary canal ever takes place has not been determined; but there appears to be no theoretical ground against this path of entrance of the organism. Spores absorbed in this way might then lie latent in the tissues until infection was lighted up by suitable local conditions.

The question occasionally arises as to whether a wound has been infected with tetanus subsequent to the time of infliction, especially when the incubation period is long. Noetzl's experiments suggest that when once granulation

tissue has covered the raw surface, infection with tetanus bacilli is extremely unlikely to occur. Pocketed subcutaneous wounds were made in sheep, and were kept open by packing with gauze without aseptic precautions; when the surface was covered with granulation tissue, in the secretion from which staphylococci were present, a virulent fluid culture of *B. tetani* was poured into the wound, which was then packed with gauze soaked in the culture. All four animals treated in this way remained alive and well. Thus, granulation tissue, in correspondence with its protective properties in general, seems to afford an almost insuperable barrier to the subsequent entrance of *B. tetani* or its toxins. Conversely, in the course of the present war Nivière has found that operative procedure on a wound was followed in a number of cases by tetanic symptoms in twelve to forty-eight hours, thus suggesting that the onset of the disease had been determined or accelerated by the disturbance of the tissues.

The occurrence of tetanus following surgical procedures—most frequently gynæcological operations—has raised a number of points which have not been satisfactorily settled. E. Koch drew attention to imperfectly sterilized catgut as a source of infection, and he produced tetanus in mice by inoculation with portions of ligature which were found surrounded by pus in a case dying from tetanus after abdominal hysterectomy for impacted fibroids. This work served the useful purpose of emphasizing the necessity for securing sterile gut, and the difficulties attendant thereon; it is well known that organisms may survive in gut which has been boiled for half an hour in absolute alcohol. It is probable, however, that a variety of causes are responsible for post-operative tetanus.

It is obvious that the *geographical distribution* of the disease should correspond with the wide distribution of the specific organism. Where the bacillus is abundant, wounds are, of course, most liable to contamination; on the other hand, where the nature of the soil is such that *B. tetani* is scanty, similar wounds will yield a lower proportion of cases; the relative frequency of tetanus at the beginning of the present war in France and Belgium, and the comparative rarity of the disease in the South African war, are illustrations in point.

As regards *sex incidence*, males are more commonly affected, apart even from war wounds, a fact explicable on the basis of occupation and pursuits. As a rule the disease is sporadic in occurrence, but of course a common source of infection may lead to the outbreak of a series of cases. There is no definite evidence as to whether individuals exhibit marked differences in *susceptibility* to the implantation of tetanus in contaminated wounds. But Dehne and Hamburger, and Aschoff and Robertson, failed to find any notable amount of antitoxin in the blood of normal individuals, thus indicating that natural immunity to the toxin is not common or well marked in the human subject.

TETANUS IN THE HUMAN SUBJECT.

In the first place, the disease will be dealt with in the form unmodified by treatment with specific antitoxin. Alterations in the clinical picture due to the administration of serum will be referred to later.

Incubation Period.—Although the transport of tetanus spores throughout the body has been proved to occur under certain conditions, this does not invalidate the view that in most cases the symptoms of tetanus are due to toxin produced by bacilli restricted to a particular site, usually a septic lesion. *B. tetani* has been recovered from the lymph glands draining the infected wound, also from the blood, lungs, and spleen in human cases (Reinhardt and Assim); but there is no evidence that a general septicæmic process occurs ordinarily. The symptoms of tetanus appear after a latent stage following infection. According to Rose's collected statistics, symptoms begin in the second week after the infliction of the wound in 46 per cent of the cases; and in the recent analysis of 180 cases treated in home military hospitals (Bruce), over 50 per cent began in the same period, more cases occurring on the tenth day than on any other (it is not stated whether any of these cases had received prophylactic doses of antitoxin); 75 per cent of the cases manifested symptoms within the first fortnight. While this is the average, remarkable variations in the incubation period are met with, ranging from one or two days to a month or even longer. Where the incubation period is unusually long, the possibility that infection has occurred subsequent to the infliction of the wound must be considered; but as will appear clearly later, a variety of factors determine the duration of the latent stage.

Symptoms.—The usual symptoms of a definitely declared attack of tetanus in the human subject are too well known to require more than brief mention; they correspond to the experimental type termed 'descending' tetanus (see p. 24). *Increased tonus of the voluntary muscles is the characteristic phenomenon.* This usually commences in the masseters ('lockjaw'), where it is often first observed on waking in the morning after a good night's sleep; by passing the index finger in between the cheek and the teeth, which are held closed, the tense anterior margin of the masseters can be very well made out. The muscles of the neck are involved practically at the same time. Then the recti abdominis, and later other groups, are affected symmetrically on both sides of the body. Finally, opisthotonus is established, this position being probably due to the relative strengths of the various groups of muscles affected. Pleurosthotonus and emprosthotonus are very exceptional. Associated exaggerated action of the unaffected facial muscles on attempting to antagonize the spastic muscles, as in the effort to protrude the tongue, causes 'risus sardonicus.' After the condition has lasted several days, exacerbations of the tonic spasm, i.e., tonic convulsions, usually tend to supervene suddenly, without warning, and not as a reflex response; these seizures vary widely in intensity, frequency, and duration (minutes to hours). Again, reflex spasms very frequently follow external stimuli of various kinds, such as handling the patient, a draught of air, bright light, noise, or in fact any sensory stimulus; or a particular act—for example, swallowing may alone excite the condition (tetanus hydrophobicus). The forearms and hands tend to remain unaffected. The senses and consciousness remain normal as a rule. The spasm of the muscles causes cramp-like sensations of varying severity. Pyrexia may or may not be present, and fever may be accounted for by mixed infection. Profuse sweats are a frequent accompaniment of the exacerbations of spasm. The violence occasionally manifested by the muscular spasms may

be appreciated from cases recorded by Anders and Morgan in which the spinous processes of the vertebræ were fractured or the teeth crushed down to the roots.* In a small proportion of cases the spasm is at first confined to the muscles of the injured limb, *partial or local tetanus* (see Courtellemont); this corresponds to the sequence of events in animals which have been experimentally inoculated—'ascending tetanus.' A degree of this phenomenon is seen when in narcosis the injured limb remains stiff although the other members are relaxed. On recovery, spasm may disappear last from the injured limb. A distribution of spasm limited to the two upper or two lower limbs has also been described. Sleeplessness is the rule after the tonic spasm has set in, and in cases which progress rapidly to a fatal termination sleep cannot be produced by any means. When sleep occurs—as the result usually of drugs—the spasm relaxes more or less completely, and commonly does not again become declared until several minutes after waking. Rose appears to have been the first to emphasize the occurrence of facial paralysis in tetanus following wounds in the distribution area of the facial nerve. Green vision has been recorded. Symptoms affecting the other systems are in the nature of accidental complications. Thus, in the period of spasm, retention of urine and constipation are common; in the convulsions, evacuations tend to occur. Respiratory and cardiac affections are dealt with below.†

Causes of Death.—The most frequent causes of death are asphyxia, exhaustion, and cardiac failure. When an exacerbation of muscular spasm affects the respiratory muscles, especially the diaphragm or glottis, death from asphyxia often occurs; hence cases in which spasm of the glottis or the diaphragm supervenes early are relatively unfavourable; such an attack may, however, cause death at a late date, when diminution in the general spasm indicates convalescence. Œdema of the lungs and pneumonia are liable to set in, and are very dangerous complications. As a result, apparently, of increased peripheral resistance during the spasm, the heart may come to a standstill either suddenly or gradually. Marked elevation of the pulse-rate is an unfavourable sign. Exhaustion may supervene rapidly; thus, an apparent improvement, in the form of diminution of the trismus, which is often accompanied by otherwise inexplicable hyperpyrexia‡, may be the herald of impending death. According to Rose, spasmodic flexion of the arms is a terminal phenomenon. Again, when convalescence appears to be established, patients whose nutrition and general condition have suffered severely may die quite suddenly. No doubt the diminished intake of food and fluid, owing to the trismus, account in part for the exhaustion and wasting, but doubtless the action of the toxin is also directly responsible.

Mortality.—All observers agree that tetanus following wounds is an extremely fatal disease; but figures collected from large groups of statistics

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* Superficial and deep reflexes are greatly increased, and Goldscheider (*Berl. klin. Woch.*, No. 10, 1915) has frequently observed the Babinski phenomenon (extension of the great toe on stroking the foot sole), either bilateral or confined to the wounded limb.

† Davies has noticed a tendency to improvement, followed by exacerbation of the symptoms, about the third or fourth day, which may be quite a feature of the disease.

‡ The temperature has frequently been observed to continue to rise for about forty minutes post mortem.

show marked variations. In general, when the incubation period is less than ten days, the mortality is greater than in cases in which the disease appears later. Permin has investigated with great thoroughness the statistics of the mortality in patients not treated with serum. Six observers who gathered their cases from the literature, found the mortality to range from 17·4 to 50·8 per cent, the figure being under 30 in three series, all Italian. Permin points out that such figures are likely to be fallacious, on account of the fact that there is a tendency to publish cases which recover or which present unusual features, and to suppress those running the ordinary fatal course. On the other hand, taking the figures of eleven observers in hospital cases, the mortality ranged from 78 to 89·3 per cent in nine; while the two others, both Italian, gave the mortality as 44 and 34·9 per cent. Permin's own series of 124 cases taken from the records of the larger hospitals in Denmark (and not including tetanus neonatorum), along with Faber's Danish series of 75 cases (each series by itself giving practically the same result), making a total of 199 cases, gave the following figures:—

Incubation	of 10 days or less,	94 cases;	deaths	= 94·7 per cent
„	of over 10 days	57 „	„	= 70·2 „
„	unknown	48 „	„	= 58·3 „

Thus, the average mortality was 79 per cent. This corresponds well with the general average of hospital figures already quoted. Only the Italians seem to have a much milder type of disease. Rose's collected hospital statistics of cases following wounds, from his own wards, from Great Britain, and in the American Civil War—in all, 716—yielded a mortality of 88 per cent, the extremes being 84·2 and 89·3 per cent.

Duration of the Disease.—Four-fifths of the fatal cases die within a week of the onset of symptoms, and over 90 per cent are dead within fourteen days (Rose). Death after the case has lasted a month is a rarity. In cases which ultimately recover, the spasm may persist for many months, the masseters being the last muscles to become free. In a case of Rose's, the last exacerbation was observed on the fifty-eighth day of the disease, and trismus was still noticeable on the seventy-fifth day. In another case the exacerbations occurred over a period of five months. Persisting stiffness of the joints of the lower limbs may require treatment by passive movement, as after fracture; it is probable also that impairment of muscular movement results from cicatrices following tearing of the muscle fibres.

Prognosis.—As has been seen under *Causes of Death*, the prognosis in this disease is always extremely doubtful. Those cases in which the spasm sets in after a short incubation period—under ten days—or in which successive groups of muscles become involved in rapid succession (which usually happens when the incubation period is short), are the least favourable. The occurrence of spasm in the diaphragm (pain in the hypogastrium and base of the chest) and glottis (stridor) is in itself a bad omen. But exhaustion, pneumonia, or cardiac failure may supervene unexpectedly at any period. According to Hill's observations, the most important point in prognosis is the time during which the patient has already survived the disease. If the case has lasted less than ten days, the chances of death are greater than of recovery; after ten days of illness the chances of recovery progressively increase.

Hyperpyrexia is a bad sign, and a temperature over 104° F. on or before the fifth day, practically always means death.

Premonitory Symptoms.—A number of observers have drawn attention to early or 'premonitory' symptoms. Where they are recognized, specific serum treatment can be begun without loss of time; the vital importance of avoiding delay in the administration of antitoxin will be discussed later. Where patients are already under observation, the occurrence of premonitory symptoms can, of course, be watched for. A number of observers have recorded the occurrence of pain in the wounded limb, which was taken to be 'rheumatic' in character, or of twitching or contracture in the muscles in the affected part, with or without marked pain. A temperamental change, such as the development of quarrelsomeness, has also been noted. Evler, who himself acquired tetanus, gives an extended list of early symptoms, as follows :—

A day or so after the infection there may be general restlessness, changing suddenly to a desire to rest.
Sleeplessness, with distressing dreams and, it may be, nightly delirium.
Difficulty in micturition, due to spasm of the sphincter vesicæ, which may last from a few minutes to half an hour.
Temporary giddiness, violent headache, excessive yawning.
The facial appearance changes and the patient looks anxious, though there is no risus sardonicus yet.
There may be trembling of the tongue, which is put out to one side.
There is often a profuse sweating, and darting pains in various parts may occur.
The patient may have a feeling of chilliness, and there may be some swelling, without redness locally, of the injured member, and throbbing of its arteries, notwithstanding that the limb is raised.
Slight jerking may follow pressure on the flexor tendons, and these muscles may be noticed to be in a condition of increased irritability.

If symptoms such as these are present, with a history of possible infection with the tetanus bacillus, Evler considers that the administration of serum is justified. The later symptoms include :—

Increased flow of saliva.
Reflex cramps of œsophagus.
Ocular symptoms, e.g., nystagmus, strabismus.
Ear trouble, and spasmodic cough.
Tremors and clonic spasms, which are not painful, and which may not attract attention.
Pain persisting after muscular contraction induced by effort.

With regard to these early symptoms, MacConkey says, " I have carefully read through a considerable number of cases of tetanus described in the literature, and I have found that practically all the symptoms mentioned by Evler have been noticed as being present early in the disease. All have not been observed in the same patient, but usually the one or two present have been sufficiently prominent to force themselves upon the notice of the physician, and, if he had read Evler's paper, to remind him that such a disease as tetanus might be before him." On the other hand, a criticism which has been passed on these observations is that, on reading them, all would feel that

they had those symptoms themselves (Embleton). But when there is the possibility that one may be dealing with so grave a disease as tetanus, it is surely advisable to be on the watch for symptoms such as Evler has described, the significance of which is, of course, unknown to the ordinary patient.

Diagnosis.—*Bacteriological.*—The occurrence of 'drumstick,' spored bacilli in the discharge from a wound is highly suggestive, but not conclusive, since other organisms practically identical in appearance with *B. tetani* are met with; and *B. tetani* in the non-spored condition is not characteristic. A much more certain procedure than microscopic examination is the production of tetanus in mice, either by the direct subcutaneous injection of secretion from the wound or by filtrates of anaerobic fluid cultures; the latter may give a positive result where direct inoculation fails to produce tetanus (Dean and Mouat), but results are obtained too slowly to be of use for treatment. The cerebrospinal fluid shows no abnormality in the albumin or cell-content, and no coagulum formation (Stintzing, Plaut, Rehn and Schottmüller), points of importance in diagnosis. The demonstration of toxin in the patient's blood or cerebrospinal fluid when several cubic centimetres are injected subcutaneously into mice, may be successful early in the course of the disease. According to several observers, failure to obtain fluid on entering the subarachnoid space is frequent in cases of tetanus; others again find the pressure of the fluid increased. There is no characteristic leucocytosis.

Clinical Differential Diagnosis.—Masseter spasm occurs in a variety of local lesions—dental abscess, abscess of the temporomaxillary joint, angina, parotitis, irritation associated with the eruption of wisdom teeth—which must be excluded should trismus be the only sign. *Spasm of the neck muscles* occurs in meningitis and cerebral abscess, but trismus is absent in these conditions, and the general features are unlikely to cause confusion with tetanus; in meningitis, too, the cerebrospinal fluid is abnormal. In *tetany*, the marked spasm of the hand muscles, leading to the 'obstetric position' of the fingers, is usually a prominent feature; further, the spasm comes and goes, which is not the case in tetanus. *Strychnine poisoning* is characterized by the presence of reflex spasms from the outset, with intervals of relaxation during which, in contrast to tetanus, the masseters and neck muscles also relax completely.

EXPERIMENTAL PATHOLOGY AND SERUM THERAPY.

As has been noted, the muscles first affected by spasm in man are usually the masseters, wherever the site of the infected wound may be; thence the affection spreads to other muscular groups—*descending* tetanus. This is the case likewise in the horse and other large animals. In smaller animals, on the other hand, when inoculated with tetanus toxin or bacilli, either subcutaneously or intramuscularly, the spasm begins, as a rule, in the muscles of the inoculated limb, and spreads later on to the rest of the body—*ascending* tetanus; with a small dose of toxin, spasm may remain confined to the inoculated limb.

The action of tetanus toxin has formed the subject of a great amount of experimental investigation, the principal contributors being Marie and Morax, Meyer and Ransom, and Permin. The practical as well as the theoretical

importance of this work can scarcely be overrated, since upon a clear understanding of the pathology of the disease, as elucidated by the action of toxin and antitoxin under experimental conditions, depends the successful application of antiserum therapy. The following summary of the principal facts and the theoretical considerations to which they have given rise takes no account of the historical development of the subject, as the present comparatively complete state of knowledge depends on the verification and amplification of one observer's work by others.

The local muscular spasm of 'ascending' tetanus is due to the action of the toxin on the related segment of the spinal cord. The toxin reaches the cord by passing up the muscular nerves. This has been demonstrated by the following experiments taken in conjunction :—

1. Taking advantage of the fact that tetanus toxin when injected into a muscle soon reaches the nerve supplying the muscle, and when in the nerve is practically insusceptible to the neutralizing action of antitoxin contained in the blood and lymph, a rabbit is passively immunized by an intravenous injection of antitoxin, which soon reaches the lymph, and then receives a relatively small dose of tetanus toxin into the muscles of the hind leg ; the result is that *local tetanus develops in the inoculated limb and nowhere else* (*too large* a dose of toxin will spread *in the cord*—see p. 27). The same result follows if antitoxin is injected into the thigh muscles and toxin is introduced into the sciatic nerve at the same spot. But if in such a passively immunized animal the sciatic nerve be first cut below the gluteus maximus, and then toxin be injected into the peripheral end, no tetanus occurs. Subcutaneous injection of toxin produces no effect in a passively immunized animal.

The rate of ascent of toxin in the muscular nerve may be judged from the following experiment :—A series of rabbits are immunized intravenously with antitoxin, and then several times the lethal dose of toxin is injected into the leg muscles ; at varying times thereafter in different animals, the sciatic nerve on the same side is cut just below the gluteus. It is found that if an interval of five hours or more is allowed to elapse between the injection of the toxin and the neurotomy, local tetanus develops.

If the posterior nerve roots only of one leg are cut, and then later on, after the animal has been passively immunized intravenously, toxin is injected into the muscle of the neurotomized leg, no tetanus follows ; a similar injection on the sound side causes spasm as usual. But the injection of toxin into intact posterior nerve roots does not produce tetanic spasm. This is of importance in connection with Sherrington's work (see below).

2. If antitoxin is injected into the sciatic nerve and then toxin is immediately injected into the corresponding limb, tetanus fails to occur in that limb. The intraspinal injection of antitoxin also prevents ascending tetanus.

3. The spasm, when recent, disappears during general narcosis, also on the injection of cocaine intraspinally. On the other hand, after spasm has existed for some time (over thirty hours), changes occur in the affected muscles, for even section of the motor nerve does not then entirely abolish the spasm.

4. Direct injection of toxin into the spinal cord causes tetanus starting, after a very short incubation period, in the muscles innervated from the site of inoculation ; but there are also symptoms of pain, restricted to the part innervated from the site of injection (see below, *tetanus dolorosus*). The extremely short incubation period after direct injection of toxin into the substance of the cord—three to five hours in cats, as compared with twenty-eight to thirty hours after subcutaneous or intravenous injection—leads Meyer and Ransom to attribute the ordinary incubation period in great part to the time taken by the toxin in ascending the peripheral nerves.

The Nature of the Nervous Lesion in Tetanus.—It has been supposed that the anterior cornual cells of the cord are irritated by the toxin, thus giving rise to increased muscular tonus. These cells are said to exhibit a definite lesion, viz., swelling of the Nissl bodies without disturbance of their arrangement (Flatau and Goldscheider), and recently Manouelian has described other characteristic changes in the motor cells of the cord, pons, and medulla; how far these lesions are the cause of the muscular spasm remains uncertain, however. But it is important to note that there are, in addition, degenerative changes widespread throughout the ganglion cells of the central nervous system, including the cerebral cortex (Foulerton and Campbell Thomson).

According to Sherrington's investigations on animals poisoned by tetanus toxin, there exists a *disturbance of reciprocal innervation.* Thus, stimulation of that area of the cerebral cortex which in a healthy animal causes opening of the mouth—due to contraction of the depressors of the jaw, accompanied by relaxation of the elevators—in a tetanic animal leads to trismus, since the normal inhibition of the closing muscles, which form the more powerful group, is now converted into a stimulation of them. The condition greatly resembles that of 'decerebrate rigidity' in an animal whose cerebral hemispheres have been removed. Clinically, the patient with tetanus exhibits the same phenomena, since the effort to open the mouth, instead of inhibiting the closing muscles, leads to excitation of them, so that his mouth closes all the tighter. The site of the lesion would appear to be in the neighbourhood of the connection between the upper and the lower motor neurons.

The general muscular spasm of 'descending' tetanus depends on the diffused action on the nervous system of toxin widely disseminated by the blood and lymph. Even in small animals, when the injection of toxin is made into a non-muscular region, e.g., subcutaneously near the knee-joint (Zupnik), general descending tetanus results. Whether the toxin passes to the central nervous system directly from the blood stream, or whether it can reach the nerve centres only by way of the muscular nerves after being taken up from the lymph by the nerve-endings, is a point which has not been satisfactorily determined. After toxin has been injected intravenously, it is possible, by introducing antitoxin into one sciatic nerve, to prevent the occurrence of spasm in this leg; this result may be due not to the antitoxin blocking the ascent of toxin in the nerve from the periphery, but to its having passed up to the spinal centres and exercised its neutralizing action in the latter situation.

Those who uphold exclusively the neural route have sought to explain the regular commencement of tetanus in the masseters on the ground of the shortness of the nerve, or of its having a greater affinity for the toxin than other nerves. It is not the case, however, that the sequence of onset of spasm in particular muscles depends entirely on the length of their nerves, since in cats spasm begins in certain muscles of the fore-limbs, the nerves of which are among the longest (Meyer and Ransom). Another view is that the centres of the earliest affected muscles have a special 'predilection' for the toxin. A probable explanation of the early appearance of trismus is that the weak action of the antagonizing muscles renders the spasm of the masseters

obvious (Zupnik); this is in harmony also with the fact that trismus may exist as the only symptom for days before the involvement of other muscles is apparent.

While the muscular nerves act as excellent and rapid conductors, they do not bind the toxin as the central nervous system, especially the grey matter, does (Wassermann and Takaki). The precise mode of conduction in the nerve has not been decided. Marie and Morax, Meyer and Ransom, and others, consider that the axis cylinder is the conductor. In support of their view, Meyer and Ransom quote an experiment in which a rabbit, very highly immunized to tetanus toxin, died of tetanus as the result of the injection of toxin into the sciatic nerve, its blood—and consequently also the lymph—at the time of death containing more antitoxin in two drops than sufficed to neutralize all the toxin injected. But Field (quoted by Park), and Aschoff and Robertson, hold that the toxin ascends in the neural lymphatics. Experiments showing that toxin injected into a muscle fails to pass into its nerve when the nerve has been cut high up a considerable time previously, do not really support the former view; while the fact that toxin which has reached the nerve is insusceptible to neutralization by the circulating antibodies in an immunized animal, can probably be explained by the comparatively slight access of lymph which is possible in that situation; the consequence is that when toxin has once entered the nerve, its action becomes concentrated exclusively on the nervous system. This appears also from the fact that a very much smaller dose of toxin will cause fatal tetanus when introduced intraneurally than when injected into the blood stream or subcutaneously.

When the toxin reaches the cord, it does not remain localized, but spreads; thus, if section of the cord is performed in the upper lumbar region, and afterwards toxin is injected into the sciatic nerve, tetanus remains localized in the hind limbs; whereas if the cord is intact, the anterior part of the body becomes spastic also.

A number of other interesting facts have also been elicited; as, for example, the observation of Meyer and Ransom that an injection of toxin into the posterior nerve-roots between the ganglion and the spinal cord does not produce muscular contraction, but causes severe pain, which recurs in spasms (tetanus dolorosus); the pain is also produced reflexly by slight stimulation of the skin supplied by the affected nerve, as by blowing on it. Again, the injection of an otherwise fatal dose of tetanus toxin into the infra-orbital nerve of a dog caused very little effect of any kind—there being in one animal spasm of the ear on the side of the injection, and in another spasm of the masseter. The fact that tetanus dolorosus never occurs clinically, or after intravenous or intraneural injections of toxin, is held by Meyer and Ransom as a proof that, under natural conditions of infection, the toxin reaches the cord only by the axons of the motor nerves, not by lymphatics; the posterior-root ganglion cells are considered to oppose an insuperable barrier to the toxin reaching the cord by sensory nerves. Loewi and Meyer have observed that the injection of a sublethal dose of tetanus toxin into a nerve renders an animal hypersensitive to a subcutaneous dose of the toxin administered some days later; this may have a bearing on the pathology of relapses.

The spontaneous convulsive seizures are probably of cerebral origin.—The evidence in favour of this conclusion is as follows :—

1. Clinically, in many instances the seizures are not associated with any obvious peripheral stimuli.

2. Roux and Borrel observed that intracerebral injection of tetanus toxin caused epileptiform convulsions; but there remained the possibility that this might be due to the mechanical irritation of the injection. Permin accordingly produced what was in effect an intracerebral injection without this possible fallacy, by introducing the toxin into the vitreous humour in rabbits previously passively immunized by an intravenous injection of antitoxin. The result was the development of recurring universal spontaneous convulsions, with practically no tonic spasm (as has been seen, the latter is produced by toxin acting on the spinal cord).

3. Confirmatory observations made by Permin were : (*a*) The occurrence of convulsive spasms in the leg of a rabbit which, by means of an intraneural injection of antitoxin, was prevented from sharing the general tonic spasm produced by an intravenous administration of toxin; the non-spastic leg participated equally with the others in the convulsions; (*b*) In such an animal, the removal of all brain substance from below the corpora quadrigemina upwards abolished the convulsions, whereas, when the animal recovered from the effects of the ether under which the operation had been performed, the general tonic spasm remained marked.

4. As has been noted, marked lesions of the cells of the cerebral cortex have been found (Foulerton and Campbell Thomson).

Of course, in the naturally occurring disease, both the brain and the spinal cord are exposed to the action of the toxin.

There are a number of further points regarding the behaviour of toxin and antitoxin, and their interaction in the tissues, which have a direct bearing on the prophylaxis and treatment of the disease. Tetanus toxin reaches the blood stream when there is a local infection; this has been proved both in animals and in man, and it has been found that the amount of toxin present in the blood is usually at a maximum before and at the commencement of the tetanic symptoms (McClintock and Hutchings). Toxin also has been demonstrated in the cerebrospinal fluid in human cases (Permin, Stintzing); positive results here are obviously more important than negative. When a fixed amount of tetanus toxin is introduced directly into the blood stream, it disappears rapidly from the circulation, this no doubt being due partly to its passing into the lymph, but also to its combining with certain tissues, especially the central nervous system. Even after the toxin has been removed from the blood, it is, up to a certain point, still capable of being neutralized by a subsequent injection of antitoxin—that is to say, the antitoxin exerts a 'curative' effect; but with the lapse of time it becomes more difficult to produce cure. This is proved by the experiments of Dönitz, who injected a lethal quantity of tetanus toxin intravenously into rabbits; thereafter he injected antitoxin intravenously at increasing intervals, and determined the amount necessary to save life at different times. It was found that when the interval between the injection of toxin and antitoxin was an hour, over ten times as much antitoxin was required as sufficed if the interval was only four minutes.

In applying these results to the treatment of human cases, it is necessary to realize precisely what the conditions are when symptoms have appeared: (1) Toxin has reached the central nervous system, and a certain amount, though probably only a portion, of the toxin has had time to enter into firm combination, and has injured the nerve cells; (2) Toxin is circulating in the blood and lymph as well as in the nerves throughout the body; (3) Toxin is probably still being produced at the site of the wound.

Experimental Serum Therapy.—Now, as regards the means at disposal for combating these conditions, toxin in the blood and lymph can be neutralized by antitoxin injected either subcutaneously, intravenously, or intramuscularly. In order that toxin diffused throughout the body may be neutralized, a similar diffusion of the antitoxin must be attained; the subcutaneous injection of antiserum, however, produces this result only slowly, about two days being required before the antitoxin content of the blood reaches a maximum (as Henderson Smith showed for antidiphtheritic serum, and Dehne and Hamburger for tetanus antitoxin). Hence, in order to ensure rapid neutralization of the circulating toxin, antitoxin should be administered intravenously; it has been found experimentally that half an hour after an intravenous injection of antitoxin, both blood and lymph are rendered atoxic (Ransom).

When we come to consider the conditions which are present in the nervous system, there is more difficulty. The central nervous system is not, like the rest of the tissues, bathed by lymph, which in its composition is closely related to blood plasma; the cerebrospinal fluid which permeates the nervous tissue is peculiar in being extremely poor in protein, and it is well established that antibodies and drugs do not pass readily into it from the blood stream (see Dixon and Halliburton). Hence, however rich the blood may be in antitoxin, whether introduced or as the result of active immunization, the concentration of antibodies will be low in the fluid surrounding the nerve cells. This explains the fact that a highly immunized animal is susceptible to a comparatively small dose of tetanus toxin introduced directly into the nervous tissue, since it must be remembered that the protective action of antibodies is due to their being present in the surrounding fluid and so neutralizing toxin before it can combine with susceptible cells. In order to bring antitoxin into the closest possible contact with the nervous tissue, various workers have recommended the intraspinal injection of antiserum, and Park and Nicoll have shown experimentally in the clearest fashion the efficacy of this form of treatment. They injected twice the fatal dose of tetanus toxin into the hind leg in guinea-pigs, and seventeen to twenty-four hours later introduced antitoxin by various routes into different animals, viz., subcutaneously, into the general circulation (intracardiac), and intraspinally. The results were as follows:—

6	animals	were treated	subcutaneously	—none survived.
15	,,	,,	intracardially	—2 survived.
16	,,	,,	intraspinally	—13 survived.

Further, the dose of antitoxin which was efficacious when administered intraspinally was much smaller than that injected into the blood stream. In view of these results it is difficult to comprehend how any theoretical considera-

tion should be allowed to stand in the way of the intraspinal treatment of tetanus. It has been objected that antiserum does not enter the nerve cells; but experiments have shown that toxin which has been bound by tissue cells can be removed by contact with a solution containing antitoxin (Besredka, Noon, Graff and Menschikoff). Injection of antiserum into the lateral ventricles has been advised, but does not commend itself on account of the danger of damaging the cerebral tissue; even if this be obviated (Ballance), the method appears unsuited for frequently repeated injections. Again, to inject antitoxin into all the nerves in a case of general tetanus is obviously impossible even if it were desirable, and as Park and Nicoll point out, intraspinal injection probably achieves the same result. The necessity for commencing antitoxin treatment at the earliest possible moment has already been emphasized; the following experiment demonstrates quantitatively the vital importance of attention to this point. MacConkey determined the amount of antitoxin sufficient to save the life of a guinea-pig when injected under the skin *simultaneously, but at another site*, with a dose of toxin just sufficient to kill an untreated animal; he then found that (1) one-tenth of this amount of serum sufficed to neutralize 100 fatal doses of toxin when toxin and antitoxin were *mixed together in vitro prior to injection*; and (2) two thousand times as much serum was required to save the life of the animal when injected *twenty-four hours after the toxin*, i.e., at a time when symptoms of tetanus had already appeared. In other words, the amount of antitoxin required to cure the animal was two million times as great as the amount which, mixed in the test tube, would render the same dose of toxin inert.

PROPHYLACTIC TREATMENT, ESPECIALLY THE USE OF ANTISERUM, AND MODIFICATIONS OF THE DISEASE DUE TO SUCH TREATMENT.

Laboratory experiment, as well as veterinary practice, have demonstrated the high value of antitoxic serum—derived from horses immunized by injections of tetanus toxin—for the prevention of tetanus. Thus, Vaillard quotes the result of the preventive inoculation of 13,124 animals during the years 1898–1906 in the practice of eight veterinary surgeons, with no cases of tetanus; while in two other veterinary practices during the same period, 139 cases occurred in untreated animals. Mohler and Eichhorn have determined that 500 U.S.A. units is a sufficient prophylactic dose for a horse, even when infection has occurred four days prior to the injection of antitoxin. In the United States the value of antitoxin in preventing tetanus as a consequence of 'fourth of July' injuries has also been clearly apparent; thus, the number of deaths from tetanus fell from 417 in 1903, to 150 in 1909, and 3 in 1914, a reduction " far out of proportion to the reduction in the number of accidents from which tetanus might have resulted " (*Jour. Amer. Med. Assoc.*, No. 26, 1915).

With regard to the prophylactic use of antitoxic serum, the following points require consideration: (1) *Dosage and route of introduction of the serum;* (2) *Duration of immunity thus conferred.*

As regards *dosage and route of introduction of antitoxin*, there is a consensus

of opinion among observers in different countries that for the great majority of wounds 500 to 1000 U.S.A. units* represents a sufficient prophylactic dose when injected subcutaneously, preferably as soon as possible after the infliction of the wound, or at least within twenty-four hours afterwards. Results obtained during the present war have in this respect confirmed previous experience (see MacConkey's summary of the literature). In the British Official *Memorandum on the Treatment of Wounds in War* (July, 1915), it is stated that there is no evidence that 500 U.S.A. units is an insufficient dose if given promptly. But the broad principle may well be followed, that " as the amount of soiling of the wound and contusion of the tissues increases, so should the amount of antitoxin be increased " (MacConkey).

As to the route of introduction, it is recommended by some that the injection be made in the vicinity of the wound, so that the toxin may be neutralized before it can diffuse; but in any case, the result of a subcutaneous injection is to render the blood and lymph antitoxic, so that toxin is neutralized before it can reach the nervous system. After a subcutaneous injection the antitoxin content of the blood reaches a maximum in forty-eight hours. This is sufficiently rapid to prevent the outbreak of tetanus in most cases; but occasionally, whether as the result of the introduction of very large numbers of tetanus spores or of some special favouring condition, symptoms of tetanus may appear in spite of the prophylactic injection. Thus, Wolf records the case of a grenade wound which tore the tendo Achillis from its attachment and splintered the os calcis, and in which the early injection of 20 German units failed to prevent the appearance of trismus thirty hours after the infliction of the wound; the patient received further antitoxin and drug treatment, and recovered. In view of the extremely short incubation period, it is probably safe to say that without the use of antiserum this case would certainly have died. Intravenous administration causes the rapid diffusion of antitoxin throughout the body fluids; accordingly this method would probably prevent a proportion of cases which occur after subcutaneous treatment, and the same dose or even less would suffice. In a number of instances (see Montais, Pozzi) the occurrence of tetanus commencing in the wounded limb, and either spreading to the rest of the body or remaining localized, has been observed in cases where antitoxin was administered during the incubation period, but too late to prevent altogether the outbreak of tetanus, e.g., two to four days after the infliction of the wound. Thus, the effect is similar to that where an animal is passively immunized and toxin is injected intramuscularly or intraneurally. When the leg is affected in such cases, the first evidence of tetanus is that the foot becomes fixed in the position of equinus, the spasm being aggravated by any local stimulus or by attempts at voluntary movement; later, the whole limb is rigid, and any stimulus causes painful exacerbation of the spasm (*partial* or *local* tetanus).

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* Forty U.S.A. units are equivalent to 1 German unit, also known as 1 Behring unit or 1 A.E. The U.S.A. unit of tetanus antitoxin is ten times the least quantity of serum which is required to preserve the life of a 350-gram guinea-pig for ninety-six hours when mixed with the official test-quantity of standard toxin (100 minimum lethal doses) and injected subcutaneously. Commercial sera frequently contain 1500 U.S.A. units in a volume of about 10 c.c. and consist of 'concentrated' antitoxin, i.e., a considerable amount of the albumin has been removed by fractional precipitation of the serum.

The local application to wounds of dried antitoxin in the form of a dusting powder has been recommended, and, as the result of experiments, Robertson suggests that a more efficient procedure is to apply a dressing impregnated with antiserum; of course this should not replace the injection of antitoxin.

Duration of Immunity.—It must be remembered that the passive immunity conferred by an injection of antiserum derived from another species is of relatively short duration, and it has been found both in the human subject and in animals, that the immunity will have fallen to a comparatively low level after the end of a week following the injection of antitoxin, as shown by the content of the serum in antitoxin (Dehne and Hamburger, Levin). On the other hand, clinical estimates of the duration of protection afforded by a dose of antitoxin based on the date of development of the disease afterwards, yield extremely divergent results (see MacConkey); this is readily understood when one remembers how many variable factors are concerned, such as the extent of the wound, the number and possibly the virulence of the tetanus bacilli introduced, the local conditions favouring multiplication of the bacilli and absorption of the toxin, etc.

It might be thought that in order to maintain immunity for a long period it would merely be necessary to administer more serum at the beginning. But this is not the case; the antitoxin disappears largely in virtue of its association with the foreign protein of the horse-serum, which is disposed of by the tissues, and there is no basis for supposing that double the amount will persist in circulation for double the time. Further, the amount of antitoxin which reaches the blood after a subcutaneous injection varies greatly in different persons who have received the same dose, thus indicating that there is also a marked individual factor in the destruction of antitoxin. Repetition of the subcutaneous dose of antiserum is strongly indicated at weekly intervals so long as the wound is not definitely in a healing stage, and especially if necrotic tissue be still present.

Antitoxin does not appear to be effective in leading to the destruction of tetanus bacilli in a wound; on the contrary, in persons immunized with antitoxin, septic wounds may continue to harbour living virulent tetanus bacilli for many weeks. Antitoxin treatment, therefore, has created many wound carriers of tetanus, who on this account may be a source of danger to others as well as to themselves; whether in the absence of prophylactic treatment with antitoxin many individuals may receive *B. tetani* into the tissues at the time of injury and continue to harbour the organism in a septic wound without developing symptoms of tetanus (as in a case recorded by Dudgeon, Gardner, and Bawtree) is not clear, but there can be little doubt that the employment of antitoxin has greatly multiplied such carriers. The danger which a tetanus carrier himself incurs is due to the fact that his infection does not appear, as a rule, to excite his own tissues to develop any considerable degree of active immunity (Löwy). Hence, if the process of healing of the wound has not led to the elimination of *B. tetani* or the formation of an efficient granulation-tissue barrier against absorption, the effects of the toxin will become manifest when the passive immunity has expired; there is also always the possibility that increased proliferation of the bacilli, accompanied by increased toxin formation, may occur, or suitable conditions for toxin absorption may develop,

and so lead to fatal tetanus. These considerations probably afford a full explanation in many cases of the long incubation period of the disease observed in patients who have received prophylactic injections of serum (e.g., two months in a case recorded by Don, and five months in a case of Teutschlaender's),* and also of spontaneous recurrences (Brandt).

The outbreak of the disease at a late stage is specially liable to occur when further operative procedure is undertaken on an infected wound, since the solution of the granulation-tissue barrier permits the spread of infection and the absorption of toxin. Bérard and Lumière have drawn attention to several distinctive features which may be presented by such cases of *delayed tetanus*; thus, the onset may be insidious, the tonic spasm, which may be localized in the wounded limb, progresses very gradually, and trismus and stiffness of the neck may remain slight for days or even weeks; permanent contracture of the abdominal muscles is, however, said to be strikingly constant. Convulsive seizures are absent, or appear late and are slight. In spite of the gradual onset and slow evolution of the disease, however, the prognosis in such cases is grave, death occurring from asphyxia owing to the contracture of the respiratory muscles. It is, therefore, an excellent rule to administer a prophylactic dose of antiserum subcutaneously twenty-four to forty-eight hours before operating on a patient with an infected wound; or if an emergency operation is required, antitoxin should be administered intramuscularly five or six hours earlier, or an intravenous injection may be given immediately beforehand. Recrudescence of septic infection also may afford conditions suitable for the occurrence of tetanus in wound carriers. In a case recorded by Huppel, a severe shrapnel wound of the left thigh, with splintering of the bone, was cleaned out five days after infliction, and at the same time a dose of antitetanus serum was given; severe tetanus occurred three weeks later, but recovery took place. Almost four months after the original injury, erysipelas developed from a small area of the wound which alone had remained unhealed; tetanus appeared four days later, and led to death.

The administration of antiserum after the infliction of a wound does not affect in any way the details of local treatment. It is superfluous to go into this matter here, beyond saying that whatever method of wound treatment is best in allaying or preventing sepsis will also prove most efficient in obviating conditions suitable for the development of tetanus. It will probably be found that a distinct value attaches to the use of those ' disinfectants ' which can be combined with the ' physiological ' method of treatment, and which are highly antiseptic and at the same time comparatively harmless to the living tissues, such as the organic chloramides (see Dakin, Cohen, and Kenyon), and also substances like brilliant green (see Leitch, and Browning and Gilmour). Such benefit as accrues from treatment with peroxide of hydrogen or similar reagents can scarcely be attributed to the inhibitory action which oxygen exerts on anaerobes in artificial cultures.

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* In this case a grenade splinter passed through the thorax and lodged in the deep muscles of the back. Five months later fatal tetanus developed and led to death within two days. Tetanus bacilli were recovered from the tissue encapsuling the splinter, but not from a chronic empyema due to the perforation of the thorax.

With regard to the *indications for the use of antitetanic serum*, all wounds contaminated with 'rich' soil, or manure, or into which foreign bodies so contaminated have penetrated, should be regarded as highly suspicious, and the presence of much contused or necrotic tissue should be held to aggravate such suspicion. The presence in a wound of other anaerobic organisms, *B. œdematis maligni* and *B. Welchii*, etc., which have the same habitat as *B. tetani*, also indicates the likelihood that the latter is present. As has been already seen, antitoxin should be administered at the earliest possible moment, or at least within twenty-four hours. Later on, larger amounts of serum will be required, exactly how much it is difficult to say, but it may be advisable to give up to 10,000 or 15,000 U.S.A. units. The following case (Teutschlaender) is instructive as demonstrating efficacious treatment where the presence of living virulent tetanus bacilli was proved. The case was one of wound of the foot-sole due to a fragment of grenade. On the sixth day bacilli resembling *B. tetani* were found in the discharge from the wound, and 20 German units of antitoxin were given subcutaneously. Late on the eighth day transient painless contractures occurred in the sole of the wounded foot. Accordingly next day 100 units of antitoxin were injected intravenously; mice inoculated on the eighth day with secretion from the wound developed tetanus. No further symptoms of tetanus occurred; but a guinea-pig inoculated with secretion from the wound on the twenty-fifth day developed tetanus after the long incubation period of fifteen days; two mice inoculated at the same time remained unaffected.

The chances of grave anaphylactic symptoms following repeated subcutaneous injections of serum are fortunately not serious—this matter will be treated later. The further question arises, however, as to whether a case which has already received one or more injections of antiserum is thereby rendered refractory to subsequent passive immunization; in other words, whether, if a patient is to be treated again with antitoxin, the fact that he has received a previous injection impairs in any way the specific efficiency of the later dose of serum. This point has been investigated for diphtheria antitoxin by Park, Famulener and Banzhaf in the human subject, under conditions strictly comparable with those likely to arise in practice, and they conclude that *the same quantity of antitoxin is indicated whether the case has or has not received a previous injection of horse serum or globulins.* There is every reason for believing that their results apply equally to tetanus antitoxin, and this conclusion is borne out by an observation of Dehne and Hamburger on the behaviour of tetanus antitoxin in a man who had been repeatedly injected with horse serum.

The effect of the extensive prophylactic administration of antitoxin since the earlier days of the present war has had the result of practically abolishing tetanus (see MacConkey). It is true also that the organization for the treatment of wounds has been greatly perfected, and that for this and other reasons the diminution in sepsis might be held to account for the diminished incidence of tetanus; but regarding the extraordinary reduction after 'fourth of July' injuries in the United States in the past thirteen years, no corresponding revolution in the treatment of wounds can be discovered. Again, evidence such as that afforded by Wolf is extremely conclusive, and could no doubt be

readily duplicated; this observer deals with the results of a German field hospital which had been stationed several miles behind the trenches at a point on the Western front, where little change of position occurred during the whole period of observation. Prior to December, 1914, antitoxin treatment was not a regular procedure, and the cases of tetanus amounted to 1·4 per cent of the wounded. During the subsequent seven months, for the greater part of which the conditions as regards cold and wet were strictly comparable with the foregoing period, the incidence of tetanus was only 0·16 per cent; but during this latter time all cases of wounds due to grenades received antitoxin, and also those due to shrapnel where there was evidence of contamination; rifle bullet wounds were not so treated.

The use of ultra-violet light has been recommended for the purpose of killing off tetanus bacilli and spores in wounds and cicatrices; but the absorption which these rays suffer in passing through an extremely thin layer of tissue or body fluids is so great (Russ), that little practical result can be expected from the procedure.

THE TREATMENT OF DECLARED TETANUS.

It is clear from the pathology of the disease that here one is dealing with an extremely difficult therapeutic problem, since the outbreak of symptoms indicates that toxin has already combined with the central nervous system, and has exerted injurious effects. In cases in which the incubation period is short and in which symptoms develop rapidly, the damage may be irreparable before the patient comes under observation. On the other hand, a considerable proportion of cases are not of this fulminant type, and in these it is only rational to believe that adequate treatment may turn the scale in favour of recovery. The modes of death and the study of the action of the toxin afford indications for treatment. Uncombined toxin in the body fluids must be neutralized, toxin must, as far as possible, be removed from combination with the nervous tissue by the contact action of concentrated antitoxin, and purely mechanical causes of death, such as asphyxia and starvation due to the muscular spasm, must be obviated. At the same time it is to be remembered that symptomatic remedies which produce muscular relaxation can exert only a limited beneficial effect; they are themselves for the most part poisons, super-added to that of the bacterial toxin, whose action is not limited to irritating motor neurons. The *tetanus sine tetano* experimentally observed by Dönitz indicates that tetanus toxin produces a general exhausting effect which is ordinarily concealed by the prominent motor symptoms of the acute stage, but which becomes marked when the patient survives for a time.

Where spasm is already present, the subcutaneous injection of serum entails such delay in its action as may render the remedy useless; the rate of absorption is much too slow. Hence, the intravenous route is indicated; by this means free toxin in the tissue fluids will be rapidly neutralized, so that further toxin cannot reach the nervous system. This is probably the main value of moderate intravenous doses of antitoxin; but it is difficult to believe that the intimate proximity of an abundance of antitoxin in the capillary blood-vessels will be altogether without neutralizing effect on the

toxin in the central nervous system, and this is supported by von Graff's experiments. As has been especially demonstrated by Park and Nicoll, however, intraspinal injections of serum are the most effective in antagonizing the action of the toxin on the nervous tissue, and a much smaller dose achieves this result by the intraspinal route than by the intravenous. Accordingly, both an intravenous and an intraspinal dose of antitoxin should be given without delay. Where for any reason an intravenous injection cannot be given, the serum should be administered intramuscularly.

With regard to *dosage*, it is certain that much more antitoxin will be required than before the outbreak of symptoms, and even then the result will be less assured; hence the wastefulness of delay till the disease is declared, in cases where there is strong presumptive evidence that infection has occurred. Where the intravenous route alone is employed, a moderate amount of antiserum will neutralize all the toxin which is likely to be in circulation; but probably very large doses are required to influence toxin already present in the nervous tissues. Some observers record the administration of enormous amounts of antitoxin intravenously; thus, Torres has recommended 120 c.c. every six hours. This serves at least to show how much foreign protein can be tolerated, but the expense is almost prohibitive. There is, however, strong experimental evidence against administering a small dose of serum every few hours; the *concentration* attained by the antitoxin is important, hence one large dose of serum should be given. As regards the intraspinal administration of serum, antitoxin rapidly passes out of the cerebrospinal fluid into the blood (Ransom), although the reverse does not hold; hence, to maintain an adequate concentration in the subarachnoid space, repeated injections are required.

The scheme of treatment which is advocated by Park and Nicoll appears to rest on a thoroughly rational basis. It is as follows: Inject, as soon as possible, 3000 to 5000 U.S.A. units intraspinally after lumbar puncture, diluting the serum with sterile normal saline and introducing a volume of 10 to 15 c.c. according to age and the amount of cerebrospinal fluid withdrawn; the dilution aids thorough diffusion, but where there has been a 'dry tap,' inject only 3 to 5 c.c. Allow the fluid to run in slowly, by gravity if possible, while the patient is anæsthetized. Give at the same time 10,000 to 15,000 units intravenously. A similar amount injected subcutaneously three or four days later will maintain the tissue fluids rich in antitoxin for the next five days. The intraspinal injections should be repeated at intervals of twenty-four hours. It has been recommended that for several hours after the intraspinal injection the patient should be kept with the head of the bed lower than the foot, to aid the upward diffusion of the antitoxin; Doyen keeps his patients in this position, at an angle of 45° for ten hours following each injection. The immediate effect of a dose of serum may be a temporary exacerbation of the symptoms, followed later by improvement.

Certain harmful effects occasionally follow the administration of serum, especially by the intravenous or intraspinal routes. These may be grouped under the following headings: (1) *Acquired hypersensitiveness* (anaphylaxis), which is due to a reaction between the tissues and body fluids of the host and foreign protein in the injected serum; this reaction occurs only as the result

of repeated injection of serum derived from the same foreign species on each occasion, and is altogether independent of the antitoxin present in the serum; (2) *Primary hypersensitiveness*; and possibly (3) *Effects due to chemical preservatives in the serum.*

1. *Anaphylaxis* is, as a general rule, established ten days after an injection of serum; hence, if a patient has received a previous injection of horse serum, whether as diphtheria or tetanus antitoxin, ten days or more previously, he should not receive a further massive dose of serum intravenously or intraspinally without previous preparation to induce anti-anaphylaxis (see below). Neglect of this precaution has led to serious results, and might cause death.*

2. *Primary hypersensitiveness* leads to symptoms identical with anaphylactic shock; but here the effects follow the first injection. This condition is exceptional, but serious results tend to follow intravenous or intraspinal injections of serum in such individuals;† thus, if circumstances permit, it is a good rule to take measures to induce anti-anaphylaxis in all cases before administering serum by these routes. The following *method of rapidly inducing anti-anaphylaxis* is based on the work of Besredka and of Friedberger: 5 c.c. of the serum are diluted with 50 c.c. of normal saline. Of this mixture 1 c.c. is injected intravenously, and is followed at intervals by further amounts—3 c.c. after four minutes, 10 c.c. two minutes later, 25 c.c. after another two minutes. This fractional introduction of serum can be best effected with the ordinary apparatus for giving intravenous injections by gravitation, the tube connecting the reservoir to the needle being pinched in the intervals. After a further interval of ten to fifteen minutes, the full therapeutic dose of serum may be administered intravenously or intraspinally. By this means the dangers of hypersusceptibility may be reduced to a minimum. Of course, in view of the gravity of tetanus, no consideration of any kind should interfere with the prompt administration of antiserum. Park recommends that the intraspinal injection of serum should be carried out according to Sophian's method, whereby the serum is allowed to run in slowly by gravitation, 30 c.c. requiring over ten minutes to enter. According to Sophian, the blood-pressure should be observed during the whole operation, and a fall of 20 mm. pressure in an adult indicates that the safe limit of quantity has been reached; British observers, however, do not appear to regard this method of control as a valuable one (*Proc. Roy. Soc. Med.*, Therapeut. and Pharmacol. Section, Oct. 19, 1915). Therapeutic measures which reduce the dangerous effects of anaphylaxis are ether anæsthesia and injections of atropine sulphate.

3. *The effect of preservatives in the serum* (0·3 per cent trikresol being that commonly employed) has been held by some to account for injurious effects following intraspinal injection. Flexner, in discussing the question, held that increased intracerebral pressure and anaphylaxis explained the accidents,

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* Collapse due to anaphylactic shock following intravenous or intraspinal injections usually appears within a few minutes, and tends to pass off rapidly; the symptoms include convulsive movements, dyspnœa and cyanosis, soft and rapid pulse, low blood-pressure, pains in head and limbs, feeling of impending death, vomiting, and diarrhœa; coma may supervene, and in cases terminating fatally, death may not occur for some hours.

† A history of asthmatic attacks following exposure to emanations from horses should always be inquired for, as this indicates the idiosyncrasy.

since death has followed intraspinal injections of serum free from preservatives (from the Pasteur Institute). The question has been investigated by Worth Hale, Voegtlin, and lately most extensively by Auer; the results obtained vary according to the animal studied and the anæsthetic employed, but the general conclusion clearly follows that trikresol contributes to the toxic action of serum introduced intraspinally. As the respiratory centre is mainly affected, Meltzer's insufflation apparatus should be kept in readiness; and if ill effects follow the introduction of serum, a portion should also be withdrawn at once by gravitation.

Additional treatment comprises thorough cleansing of the wound, adequate special nursing and feeding,* avoidance of external stimuli, such as bright light, draughts, noise, etc., and the use of drugs which abolish the muscular spasm. The drugs used include practically all the sedatives and narcotics—chloral hydrate by mouth, chloretone in oil per rectum, morphine hypodermically, and ether inhalation (chloroform appears to be less suitable), being especially employed. The dosage, of course, is regulated so as just to secure and to maintain relaxation of the muscles.†

Recently, as a result of Meltzer and Auer's experimental work, magnesium sulphate has been much used to relax the spasm, and has been widely if not universally approved. The following account of its employment embodies the procedures of Meltzer, and of Kocher, a warm advocate of the method. The drug may be administered: (1) Subcutaneously; (2) Intramuscularly; (3) Intraspinally; or (4) Intravenously.

1. *Subcutaneous injection* suffices in milder cases; the dose is 1·2 to 2 c.c. (for a young infant 0·8 c.c.) of a sterile 25 per cent solution of $MgSO_4$ *crystals* (not anhydrous) per kilo of body weight, administered after morphine or under light ether anæsthesia. This represents a quarter of the maximum safe dose, and may be repeated four times in the twenty-four hours for a number of days. The effect is gradual.

2. *By the Intramuscular route* the dose is two-thirds of the subcutaneous, and should be injected into the thigh muscles; the site should then be massaged well. The effect is very potent when ether is used in combination; the patient is etherized before the injection, and a moderate anæsthesia is maintained for twenty minutes afterwards. The action sets in more rapidly, but is more transient, than with subcutaneous injections; on account of the local reaction, repetition is inadvisable.

3. *The Intraspinal method.*—When the case is very severe, with involvement of diaphragm and larynx—a condition most resistant to other treatment—this method produces rapid and prolonged relaxation, which sets in in half an hour and lasts for twenty-four hours. The dose is 1 c.c. of a 25 per cent solution per 10 kilos of body weight, introduced under ether anæsthesia. The patient should be kept horizontal, with the *head alone*

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* Embleton has found constantly aceto-acetic acid in the urine in cases of tetanus, however slight the spasms, and has suggested that it pointed to the possibility of death being due to acidosis; but of course the common cause of acetonuria, viz., relative carbohydrate starvation, must first of all be excluded.

† Average doses are: chloral hydrate 75 to 150 gr., or morphia $1\frac{1}{5}$ gr. daily, chloretone 30 gr. every eight to sixteen hours.

raised, for some hours; if the thoracic muscles do not relax, the head should be lowered, and it may be necessary to incline the whole body with the feet upward. Deep narcosis results, which may last for twenty-four hours. After the symptoms have been controlled by an intraspinal injection, the attempt should be made to maintain relaxation by subcutaneous administrations.

4. *Intravenous administration* produces the most rapid action; Straub employs a 2·5 per cent (i.e. isotonic) solution, from 50 to 150 c.c. of which should be injected in two minutes. Spasm relaxes in from one to five minutes, but the effect passes off in half an hour. On account of the effect of intravenous injections on the heart, Meltzer urges caution in the use of this method, and recommends injecting a 6 per cent solution at the rate of from 2 to 3 c.c. per minute; slowing or shallowness of respiration is an indication for immediate discontinuance of the injection; if this does not cause prompt improvement, inject slowly through the venous cannula 'a small amount' of 2·5 per cent calcium chloride (see below).

An objectionable effect which may follow the administration of $MgSO_4$ is paralysis of respiration, which can be counteracted at once, except in the case of intraspinal administration, by calcium chloride (30 to 40 c.c. of a 2 per cent solution intramuscularly, or 500 to 600 c.c. of a 0·2 per cent solution along with 0·6 per cent NaCl intravenously); then, of course, the spasm may also recur. An injection of 1·5 mgram of physostigmine may also be employed, but is probably less safe. Especially in the case of intraspinal administration, arrangements should always be made for insufflation of air or oxygen by Meltzer's apparatus. Kocher states, however, that with the doses mentioned the occurrence of respiratory failure is very rare, and he has not seen a fatality from this cause. Depression of the circulatory function, as shown by softness or intermittency of the pulse, is especially likely to follow intravenous administration, and is a sign for discontinuance; and if the administration is stopped when ill effects commence, they tend soon to pass off. While the necessary precautions have been gone into in detail, it must not be concluded that the method is dangerous; in fact, few remedies are so well under control provided that the administrator knows what preparations are required. Obviously, cases treated in this way must be kept under close observation, and in the use of intraspinal injections the attention must be unremitting. The remarkable property which calcium chloride possesses of immediately awakening an animal narcotized with magnesium sulphate (Meltzer and Auer) suggests that the alteration produced in the nervous tissues is, within limits, a perfectly reversible one; this is a rare and most valuable feature in any drug, and warrants a wider trial of the method. The subcutaneous injection of concentrated $MgSO_4$ is painful at the time, but the pain is said to disappear soon, whereas a weaker solution (5 to 10 per cent), though painless at first, causes pain later on (Stadler). Zuelzer employs magnesium glycerophosphate, which he states has very little effect on the blood-pressure; safe doses are of a 25 per cent solution, 10 c.c. intravenously or 5 c.c. intraspinally; intramuscularly, scarcely any pain is produced.

Baccelli's treatment consists in the subcutaneous injection of a 2 or 3 per cent watery solution of carbolic acid, commencing with the daily dose of 0·3 to 0·5 gram—the urine being observed in order to test the patient's tolerance—

and then rapidly increasing to 1 to 1·5 gram phenol daily, administered in repeated injections. A remarkable reduction in the mortality was reported by Baccelli (a collection of individual cases from the literature), which should render this the only method worthy of consideration; but a general confirmation is lacking.

Amputation of the inoculated part has been proved experimentally to serve no useful purpose in the treatment of tetanus (McLintock and Hutchings), and this coincides with the opinion of most clinical observers.

Various heroic measures have been practised as further aids in treatment, such as section of the phrenic nerves.

Coming now to the *statistical aspect*, what reduction in the mortality from tetanus has resulted from the use of antitoxin? Permin, who has collected what is probably the most satisfactory series of comparable statistics from Danish hospitals—not individual cases compiled from the literature—concludes that antitoxin therapy has an undoubted, although not a pronounced, effect in reducing the mortality. Thus he found that out of 189 cases (not including tetanus neonatorum) treated with serum, 42·3 per cent recovered, as compared with 21·1 per cent of recoveries where antitoxin was not used. The details are as follows, and the table of untreated cases is added for comparison:—

Incubation	Cases not treated with serum		Cases treated with serum	
	Number of Cases	Percentage of Recoveries	Number of Cases	Percentage of Recoveries
10 days or less ..	94	5·3	92	27·2
Over 10 days ..	57	29·8	57	59·6
Unknown	48	41·7	40	52·5
Totals ..	199	21·1	189	42·3

It might be objected that the untreated cases belonged to an earlier period, and that the severity of the disease had altered spontaneously or as the result of other treatment; but 100 of the untreated cases occurred subsequent to the antitoxin epoch, and of these only 24 per cent recovered; they were distributed as follows:—

Incubation	Number of Cases	Percentage of Recoveries
10 days or less ..	47	6·4
Over 10 days ..	32	37·6
Unknown	21	42·9
Total ..	100	24

Accordingly, the beneficial effect of antitoxin treatment appears to be clearly established, although this view is by no means universal. A closer analysis of Permin's cases did not establish any advantage following a particular route of introduction of serum, or any other factor. In comment, however, it may be said that, so far, no satisfactory detailed statistics on

the antitoxin treatment of tetanus exist, and further, until recently, knowledge as to what is even presumptively the best procedure as to dosage and route of administration has been extremely deficient. Nicoll's recently published series of unselected cases treated by the combined intraspinal and intravenous method of Park and himself, yielded 16 recoveries out of 20 patients; 9 of the cases had an incubation period of ten days or less, and 6 of these recovered. Doyen, also, has reported 21 recoveries out of 24 cases treated by large intraspinal doses of serum; 13 of the cases had an incubation period of ten days or less, and 10 of these lived. Although these series are small, the recoveries seem much too numerous to be the result of chance, and afford the hope that an effective procedure has at length been evolved for the treatment of declared tetanus.

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THREE CASES OF TETANUS FROM THE NORTHUMBERLAND WAR HOSPITAL.

I.—A CASE OF TETANUS OF PARAPLEGIC TYPE.

By E. NAPIER BURNETT and W. TULLOCH.

A soldier was admitted on Aug. 17, 1915, suffering from gunshot wounds of the right arm and left leg. [*Ref. No.* 129.]

History of Injury.—On Aug. 9, at 7 p.m., while sitting in a trench, a German shell burst overhead quite close, and two flying splinters produced the patient's wounds. A neighbouring soldier immediately applied the usual field dressing; the patient then lay down in the trench until picked up by stretcher-bearers. About midnight on Aug. 10 he was carried to a field dressing station, where his wounds were dressed and an injection of anti-tetanic serum was given into the abdominal wall. On Aug. 11 he left the dressing station, and travelling by motor ambulance and rail, he reached the Canadian Hospital on the evening of Aug. 12. On the following day a general anæsthetic was administered and his wounds were dressed; he left this hospital on Aug. 16, arriving in —— on Aug. 17.

Clinical Condition.—Aug. 17. Over the upper and inner aspect of his right arm there was a flesh wound two inches in length and three inches in width at the widest part. The edges of the wound were ragged, and the underlying exposed muscles bruised and torn, the whole surface being covered by a purulent discharge. On the left leg, about one inch to the inner side of the middle of the tibia, there was a small circular punctured wound, the edges of which were sloughing, and around the wound the skin was discoloured for a considerable area. From the punctured wound itself there was no discharge, and it was from the dry exudate covering this wound that Dr. Tulloch made his bacteriological discovery. In contrast to the right leg, the calf of the left one felt harder and more resistant to touch than normal, producing the impression that there was a coagulated hæmatoma present. Both wounds were treated with hydrogen peroxide solution, followed by hypertonic saline, and boric acid fomentations were applied twice daily.

On Aug. 18 the patient complained of having slept badly because of 'pains and jumpings' in his left leg. On examination, the left calf felt hard, as if the muscles were in a state of cramp. On touching the skin of the leg on any part below the knee, the whole of the left lower limb was thrown into a state of spasm. These spasms were readily induced, and their duration was about ten seconds each. All the reflexes of his lower limbs were much exaggerated. Because of the probable tetanic nature of the condition, and his disturbed sleep, the patient was isolated from the main ward in a side

room, and a mixture of potassium bromide with chloral hydrate was prescribed. The following night the patient again slept badly, complaining of ' pains and jumpings' in both legs.

On Aug. 19 it was evident that the condition of rigidity with spasmodic contractions had extended to both legs. When the limbs lay exposed, the left leg was obviously more affected than the right, and it was noted that the spasms were more frequent than on the previous day, being at the rate of twenty to the minute. On touching *either leg*, both lower limbs were now thrown into spasm—the spasms being always more severe in the left (injured) limb. There was no rigidity or spasmodic contraction observed then, or at any time throughout the course of the illness, in the abdominal muscles, or in the muscles of the back, head, or neck. The patient had never any feeling of stiffness of his neck or jaws, and no trismus was ever observed. Bladder and bowels acted normally and without difficulty; his temperature never rose above 99·4°, but his pulse-rate kept from 80 to 90 per minute for three weeks, thereafter gradually falling to 76.

Under the influence of alcohol and the medicine prescribed, the patient soon began to have more restful nights. The spasmodic contractions persisted fairly acutely in both limbs for fully two weeks, and then became less severe, first in the right leg, and ultimately disappearing from the left leg in about six weeks from the date of onset.

The rigidity of the calf muscles of the left leg still persists, and has lasted altogether now for five months.

Operation.—An *x*-ray picture showed a small shadow in the left calf, and on Dec. 10, when all the signs of tetanic spasms had disappeared, the patient was given a general anæsthetic, and a small piece of shrapnel was removed from the left calf by Major D'Oyly Grange. It was considered advisable before this operation to administer 1500 units of tetanus antitoxin (American), and this was given on the morning of the operation. The operation caused no return of tetanic symptoms, and the wound healed per primam.

Comments on the Clinical Symptoms.—Cases of localized tetanus have been recorded by French surgeons (Montais and Broca in *Annales de L'Institut Pasteur*, No. 8, 1915) and others, but so far I have been unable to find any instance recorded of the paraplegic type of the disease in human beings. This case is consequently of more than usual interest, because it confirms the findings of animal experiments for the first time.

Montais published a series of four cases of tetanus localized to one wounded limb. He described his cases as being typical of tetanus, but limited to the wounded limb during the whole or part of their course. Each of the four cases presented the same fundamental symptoms, namely, *persistent tonic contraction* gradually increasing in intensity, and complicated at the end of several days with *spasms, provoked by the slightest local irritation.* The maximum intensity of the attacks was reached in from one to two weeks, when the spasms gradually disappeared, leaving behind a condition of muscle contraction similar to that which ushered in the disease. This muscle contraction, unlike that in classical tetanus, persists for weeks or even months—

its persistence being probably *the* fundamental element of tetanus in its abnormal form. The primary contraction of the muscles in the wounded area commences insidiously, quite unknown to the patient, and is usually first discovered when the wound is being dressed. Montais emphasizes the diagnostic value of this symptom in these words: "A persistent hardness in a recently wounded limb should suggest tetanus."

The same writer quotes from the *Journal des Practiciens* (April 10, 1915) the following case described by Professor Broca:—

"A man, age 21, wounded by a bullet on Jan. 12, arrived at Paris on Jan. 16, when he was immediately given an injection of antitetanic serum. The injury was a compound fracture of the femur with gas infection, and the treatment consisted of free incisions, washing out the splinters, and drainage.

"The patient was an alcoholic (he admitted taking 6 to 7 litres of wine per day), and although the wounds were progressing favourably, he always seemed restless, with muscular spasms in the wounded limb; so persistent was the restlessness, that in spite of continuous extension applied to the limb, the bone ends forced their way out through the wound and became globular; there was shortening of the limb to the extent of 25 centimetres, so that I made up my mind to amputate. The restlessness continued so long, that I dismissed alcoholism as being the cause.

"Seven days after the amputation and twenty-two days from the time of being wounded, I was sure, one morning, of a very mild degree of *trismus*; the patient died five days later of asphyxiation, without having had any convulsion in the limb.

"Now, I wonder if the initial restlessness and contractions of the thigh muscles were really not symptoms of the infection of tetanus? These painful premonitory spasms have been classically described, but I had never had the opportunity of observing them."

In Montais's cases, in addition to the general treatment by chloral, morphia, and injections of 3 per cent carbolic acid, he employed local treatment, in the form of 15 per cent magnesium sulphate solution, 7 to 10 c.c. being injected intraspinally, so as to affect the lower part of the spinal cord, a larger quantity of cerebrospinal fluid having previously been withdrawn. He describes the effect of this treatment as being wonderfully soothing, especially when the spasms were severe.

Dr. Tulloch, in his discussion of the bacteriology and pathogenesis of our case which follows, indicates that a prophylactic injection of antitetanic serum is an essential factor in the etiology of paraplegic tetanus.

Now that attention has been drawn to these cases of localized tetanus, they will be found to be less rare than previous records indicate. Since the above, a second case, with contractions and spasms and exaggerated reflexes limited to a wounded arm, has been admitted under the care of Professor Rutherford Morison, to whom we are indebted for aid and counsel in the one described.

Our acknowledgments are due to Col. G. G. Adams, A.M.S., for permission to publish these notes.

DISCUSSION OF THE PATHOLOGY OF THE ABOVE CASE.

A. **Results of Bacteriological Examination.**—Before discussing the mechanism of intoxication in the case under consideration, I shall indicate the results of bacteriological examination of the wound exudates.

1. *Pus from the Wound of the Right Arm.*—Microscopical examination of this showed the presence of Gram-negative coccobacilli, staphylococci, and streptococci. Aerobic culture confirmed this finding, the Gram-negative organism being found to have the characters of *B. coli.*

Deep stab cultures of the material were made in formate agar, glucose agar, and ordinary agar. Some of these were incubated without previous heating, while others were heated to 70° C. for thirty minutes before incubation. In none of the latter did growth appear, while in the former only a few colonies developed in the line of the stab and near the surface of the medium. These proved on microscopical examination to be staphylococci.

One therefore could not regard the arm wound as the source of the tetanus intoxication.

2. *Exudate from Small Punctured Wound of the Left Leg.*—The exudate from this wound was scanty, and on microscopical examination showed the presence of but few organisms of any kind. Those present were all Gram-positive bacilli. The majority of these were somewhat larger and broader than the *B. tetani*, but among them a few slender forms were noted, and after extensive examination of the films (three in all), two typical drumstick forms were found.

Aerobic and anaerobic cultures were made from the exudate, and of the latter, a series heated prior to incubation and a series without previous heating were prepared. The media used were glucose, formate, and ordinary agar; and glucose, formate, and ordinary broth.*

In none of the aerobic cultures did growth appear, while three of the anaerobic cultures showed good growth, namely: (i) Formate agar previously heated; (ii) Formate agar not heated prior to incubation; (iii) Glucose agar not heated prior to incubation.

These cultures were examined after three days' incubation at 37° C., and the second proved to be a pure growth of a large Gram-positive bacillus with a spore placed almost centrally. It probably belongs to the group of *B. Welchii.* The first and third of the growths were found to be mixed cultures of the above organism and a more slender form which had developed a terminal spore. Notwithstanding every effort being made to isolate the latter bacillus from the growth, I failed to obtain a pure culture, the large bacillus rapidly out-growing the other, and being so intimately mixed with it that pure colonies did not appear in the plates. It was unfortunate that a pure growth was not obtained; but the morphological characters of the slender organism were so definite that no doubt was left as to its being the *B. tetani.* The presence of the two anaerobes and the entire absence of

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* None of the broth tubes showed growth, probably because the atmosphere of incubation had not been completely deprived of its oxygen. The tubes were incubated in Buchner's tubes.

aerobic organisms from the exudate form a remarkable indication of the state of the wound.

I think that from these results we may justifiably conclude that the leg wound only was infected with *B. tetani*. I draw particular attention to this, as only the lower limbs, and particularly the left lower limb, were seriously affected with tetanic spasms.

B. **Discussion of the Mechanism of Intoxication.**—In experimental tetanus of the guinea-pig and frog, there appears to be no doubt that the route whereby the toxin travels to the central nerve system is via the motor nerves, and there is evidence that absorption by blood does not occur. In man, definite information on this point is lacking, and it seems to me that the case under consideration is especially worthy of note, in that it suggests that the mechanism of toxin absorption in man is the same as that which obtains in the experimental animals mentioned above.

After the period of 'incubation' which follows the administration of the tetanus toxin to a guinea-pig, the first symptom of intoxication noted in the animal is a condition of spasm of the limb into which the inoculation has been made. Thereafter general tetanic spasms similar to those occurring in man manifest themselves; but it is to be noted that the transition from local to general tetanus is abrupt. There is no 'graduated extension' of the condition from the limb primarily affected to other parts innervated from regions of the cord in close proximity to that showing the first evidence of intoxication. If it be true of the guinea-pig that no absorption via the blood-stream takes place, it is a little difficult to explain the sudden onset of the general tetanus, unless one assumes that, once the toxin has gained access to the central nerve system (via the nerves), it is generalized throughout that system with extreme rapidity.

Let us assume that this sequence of events takes place in the natural disease in man—then we should expect a local tetanus to be a notable feature at the onset of the disease. But it is not. This absence of local tetanus in man may be due to the fact that he is much more susceptible to the intoxication under consideration than is the guinea-pig. Moreover, certain areas of his central nerve system—the cranial nuclei—exhibit a special susceptibility to tetanus, and this peculiarity determines the early onset of trismus, as well as the absence of premonitory local spasms.

If, then, we raise the resistance of man, as was done in the present case, by the prophylactic administration of antitoxin, a condition may be produced which closely resembles that of the normal guinea-pig. I submit that this is what has taken place. The central nerve system as a whole was immunized, but the immunization was insufficient to prevent intoxication at the point where the toxin entered the cord. It is as though the cells of the left lumbar enlargement were exposed to a greater concentration of toxin than the rest of the cord, and therefore showed evidence of intoxication, while the naturally more susceptible areas did not suffer, being less directly exposed to the influence of the toxin.

If this be the correct explanation of the case, it strongly suggests that in man the main route of toxin absorption in tetanus is via the nerves, *and even*

if this hypothesis cannot be accepted in its entirety, the case proves that a route of absorption is certainly via the nerves.

In conclusion, I would point out that while it is impossible to draw definite deductions from our case, I feel that the suggestion submitted above is helpful in arriving at an appreciation of the mechanism of tetanus intoxication in man.

II.—CASE OF TETANUS LOCALIZED TO RIGHT ARM.

By EVELYN RITSON.

Pte. G. P. was admitted to Northumberland War Hospital on Jan. 20, 1916, with shrapnel wounds of right arm, left arm, and scalp. [*Ref. No.* 130.]

History of Injury.—Patient was wounded on Jan. 5, 1916, while in the trenches, by a shell bursting near. Out of thirteen men he was the only one not killed. He did not lose consciousness. The head wound bled profusely, but not the arm. No vomiting. Operated on in France, and a piece of shrapnel removed from the right arm. He states that he was injected with antitoxin.

Previous to this he was wounded in the right wrist on March 15, 1915, after which he had neither movement nor sensation in the right hand for three weeks.

On Admission.—There was a longitudinal wound of the scalp over the left parietal region about one and a half inches long, and an *x*-ray plate from France showed a marking in this region suggestive of a fissured fracture. The left arm showed an oblique wound extending from the origin of the deltoid muscle forwards, and reaching nearly to the deltoid insertion; this was granulating and clean, and about one inch across at its widest. On the right arm, just above the elbow-joint and on the posterior aspect, there was an irregular longitudinal wound, about one and a half inches in length; there was a second wound just below the right elbow-joint, over the middle of the anterior surface of the forearm, about the size of a hen's egg; an indiarubber drainage-tube extended through from one wound to the other. This tube was removed at once. While the arm was being held during the process of dressing the wounds, the forearm muscles were noticed to be hard, and they were observed to exhibit clonic spasm. The fingers of the right hand remained in a position of flexion, the flexor muscles being stiff. Forcible extension of the fingers was painful. The reflexes of the right arm were exaggerated—gentle tickling of the forearm or palm of the hand caused flexion of the fingers.

Professor Rutherford Morison demonstrated the case as one of localized tetanus, pointing out the rigidity of the muscles, the clonic spasms in them, and the exaggerated reflexes, as local evidence of the disease; and the anxious, rather scared, appearance of the patient, as a general sign of the same. He thought that this variety was only likely to occur in patients who had had a prophylactic dose of antitetanic serum. Ten days later the French literature obtained by Dr. Burnett confirmed these views. There could be no doubt as to the prophylactic value of the injection; it had been proved in America before the war, and if any doubts remained they were dispelled by war results. Case III, described below, provides tragic evidence to the same

effect. As to the curative value of the serum, Professor Morison entertained the gravest doubts, and did not approve of any patients with generalized tetanus having the injection, as he felt sure he had seen some patients killed by it. In this case, as the condition was so definitely localized to the arm, he thought that the dangers of anaphylaxis and of aggravation of the disease were less than the danger of generalization, and ordered injection; 1200 units were given below the right costal margin.

Jan. 21. *X*-ray of right elbow shows a small gutter in lower end of the humerus. No foreign body.

Jan. 24. Flexion of the fingers continues, and spasms can be excited in hand. A pathological report on pus of Jan. 20 states that no tetanus bacilli were detected.

Jan. 26. Pus was negative. Flexion of the fingers not so marked. Some firmness of the upper arm muscles. Spasms can occasionally be excited.

Feb. 4. No spasms. Flexion is less marked. Feb. 6. The upper arm muscles are very firm and tender. Supraspinatus and infraspinatus also firm. Feb. 7. Pus negative. The scalp wound is healed.

Feb. 14. Flexion of the forearm muscles is still less marked. The upper arm muscles are still hard. Shoulder-girdle muscles are less rigid. Feb. 19. The left shoulder wound is healed. Rigidity of shoulder-girdle muscles is almost gone. That of the upper arm muscles, especially the biceps, is still noticeable. The lower end of right elbow is healed; the upper wound is healing, and does not allow of free drainage.

Feb. 23. The right elbow is red and swollen. Fomented. Œdema of hand. Rigidity of the forearm muscles gone, but still present in the biceps. To wear wrist extension splint. Feb. 25. Abscess formed above the right elbow. This was incised, and pus sent to the bacteriologist. The report was negative. Feb. 29. Still some rigidity in the biceps.

March 7. The sinus above the elbow is still discharging. Œdema still present, and also some rigidity in the biceps.

March 14. The sinus was opened up and two small sequestra were removed from the humerus, the cavity being packed with eusol gauze and the splint re-applied. The rigidity of biceps is not now noticeable. March 17. The gauze pack removed. Œdema of the hand.

March 27. A slight discharge from the wound continues, and there is still some wrist-drop and œdema of the hand.

Apr. 5. The wound is not quite healed, but œdema is not so marked.

Apr. 15. The wound is healed. Wrist-drop is still present, and the patient continues to wear his splint.

May 4. Sent to convalescent home. The musculospiral nerve is to be explored if there is no improvement.

III.—GENERALIZED TETANUS. DEATH FROM PNEUMONIA.

By EVELYN RITSON.

Pte. J. A., age 35, was admitted to hospital on March 9, 1916, with a shrapnel wound of the arm. A piece of shell had been removed from his arm in France on March 4. [*Ref. No.* 131.]

History.—The patient was wounded on March 1, while in the trenches, and operated on in France. He said he was *x*-rayed, and the bone found to be damaged. He has had no loss of sensation nor movement in his arm or fingers. He stated that no antitetanus injection had been made.

On Admission.—One and a half inches below the acromial end of the left clavicle, and over the anterior part of the left deltoid, there was an oblique wound, septic and granulating, which appeared to be deep. There was a firm bulging of the upper part of the biceps muscle, presenting a similar appearance to that following rupture of the long head of the biceps. Eusol dressing was employed.

March 10. *X*-ray shows a gutter in the humerus, externally, just below the head. Also a doubtfully metallic foreign body at the upper edge of the gutter. March 12. Patient complained that he could not eat his tea because his jaws were stiff. It was found that he could only open his mouth to the distance of three-quarters of an inch between the incisor teeth. There was no stiffness of the neck muscles, no marked rigidity of jaw muscles, and the abdomen was not rigid. The bulging of the biceps noticed on admission had gradually disappeared. At 10.30 p.m. 1500 units of antitetanic serum were given below left costal margin, and 10 gr. of chloretone every eight hours.

March 13. There is no marked rigidity of any muscles, but the mouth could only be opened a quarter of an inch. At 6 p.m. 1500 units antitetanic serum were given below the right costal margin.

March 14. Some rigidity of neck and abdominal muscles noticed. When the abdomen was palpated, muscles became more rigid. At 6 p.m. 1500 units antitetanic serum were given below the left costal margin. The pathological report states that no tetanus bacilli were found in the pus from the wound.

March 15. The mouth could be opened rather more than on the previous day. The neck and abdominal muscles were slightly more rigid. On palpating the abdomen it was found that the patient had a slight spasm, and at 6 p.m. 1500 units antitetanic serum were injected into the right pectoral region.

March 16. The tendency to spasms was increased, as was also the strength of the spasms. There was no permanent opisthotonus, but it occurred during the spasms. Râles were heard over the bases of both lungs, more marked on the left side. Evening temperature 103°. Respiration difficult. Antitetanic serum, 1500 units, was injected into the left pectoral region. March 17. The patient was much cyanosed, with a temperature of 104°. Breathing was difficult, and spasms occurred whenever he was touched. He seemed a little better in the evening, but died at 3 a.m. on March 18. The pathological report of pus taken from the wound on that date was negative.

Post-Mortem Report.—Rigidity of muscles was not more marked than in normal rigor mortis. Deep in the wound, lying in the gutter fracture, was found a small portion of clothing, from which tetanus bacilli were obtained. The lower lobes of both lungs showed marked congestion, and that of the left lung early consolidation. The upper lobes were of a remarkable bright red colour. There was a good deal of muco-pus in the larger bronchi, especially of the left lung. The heart appeared to be healthy.

ILLUSTRATIONS OF WAR SURGERY.

(*Continued from Vol.* iii, *page* 505.)

[Under this heading we propose to publish during the War a series of drawings illustrative of military surgery in its various aspects. The BRITISH JOURNAL OF SURGERY is indebted to Surg.-Gen. Sir George H. Makins and Surg.-Gen. Sir Anthony Bowlby for their help in the selection of cases and for their clinical remarks on certain of those selected. The notes, supplied by various officers of the Royal Army Medical Corps under great pressure of work, are necessarily brief. The drawings have been made by artists specially commissioned by the Editorial Committee.]

Exit Aperture of a Bullet Wound traversing the Forearm. (From No. 13 General Hospital, Boulogne. Under the care of CAPT. FITZMAURICE KELLY.)

The bullet entered by a type aperture upon the flexor aspect of the forearm, and caused a fracture of both bones. The drawing (*Fig.* 1) shows the angular character of 'explosive' exit wounds, the absence of any loss of skin,

FIG. 1.—Exit wound caused by a rifle bullet.

and the pointed shape of the small flaps formed by the radiation of the fissures in the skin extending from the point of the protrusion first to give way. The prominence resulting from the retraction of the torn ends of the muscles, the deep pit leading down to the fracture, and the tendency to roll up of the freed skin at the margin of the wound, are all well shown. [*Ref. No.* 116.]

Gutter Wound of the Scalp. (From No. 13 General Hospital, Boulogne. Under the care of CAPT. FITZMAURICE KELLY.)

The wound, a little to the left of the median line, was caused by a bullet. On admission, the patient complained of headache and of loss of power in both lower limbs. He did not vomit.

Three days later he could move both lower limbs, and on the fourth day the wound presented the appearance seen in *Fig.* 2. No injury to

FIG. 2.—Gutter bullet wound of scalp.

the bone could be detected, and this observation was confirmed later by a skiagram. On the fifth day, movements of the left limb were good. In the right limb, hip movements were good, those of the knee weak, and at the ankle only slight plantar flexion and no dorsiflexion were possible. The right plantar reflex was extensor. Five days later the patient was sent to England, practically well. [*Ref. No.* 117.]

Exit Wound of a Rifle Bullet. (Under the care of CAPT. A. W. DENNIS.)

The bullet was fired at fifty yards' range, and the illustration (*Fig.* 3) shows the explosive effect at such distances; the inset shows the comparatively insignificant wound of entry. There was no fracture, and the patient did well. [*Ref. No.* 118.]

FIG. 3.—DRAWING OF THE RIGHT ARM SHOWING THE EXPLOSIVE EFFECT ON THE EXIT WOUND CAUSED BY A RIFLE BULLET FIRED AT CLOSE RANGE. THE INSET ILLUSTRATES THE WOUND OF ENTRY.

Shell Wound of Right Arm. (From No. 9 Casualty Clearing Station. Under the care of CAPT. DEW.)

FIG. 4.—Shell wound of arm.

The posterior aspect of the arm is seen in the illustration (*Fig.* 4), which shows the extensive laceration of the triceps muscle. The bone was not fractured. [*Ref. No.* 125.]

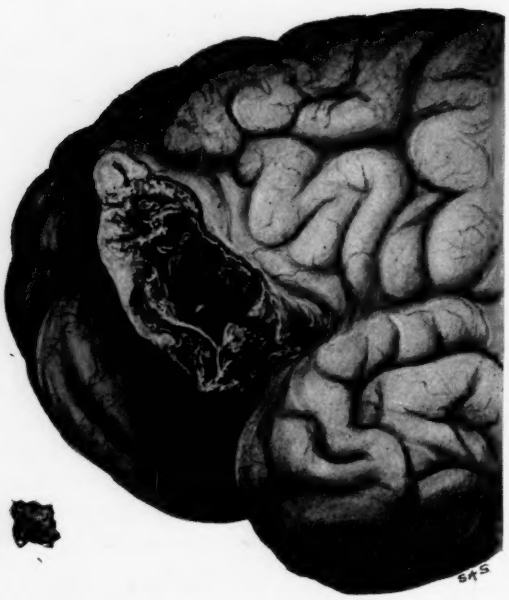

FIG. 5.—Shell wound of brain—the small figure illustrates the shell fragment.

Wound of Brain by a Fragment of Shell. (From No. 10 Casualty Clearing Station. Under the care of CAPT. DEW.)

The illustration (*Fig.* 5) shows an abscess of the left frontal lobe which had resulted from the penetration of a very small fragment of high-explosive shell. Most of such wounds can be prevented by the helmets now in use.

Shell Wound of the Leg, with Compound Fracture of Tibia and Fibula, and subsequent Gas Gangrene. (From No. 10 Casualty Clearing Station. Under the care of CAPT. VELLACOTT.)

FIG. 6.—SHELL WOUND OF LEG.

The illustration (*Fig.* 6) shows the condition twenty-four hours after the injury. [*Ref. No.* 119.]

Wound of Stomach caused by a Bullet from a Machine Gun. (From No. 17 Casualty Clearing Station. Under the care of CAPT. MEIER.)

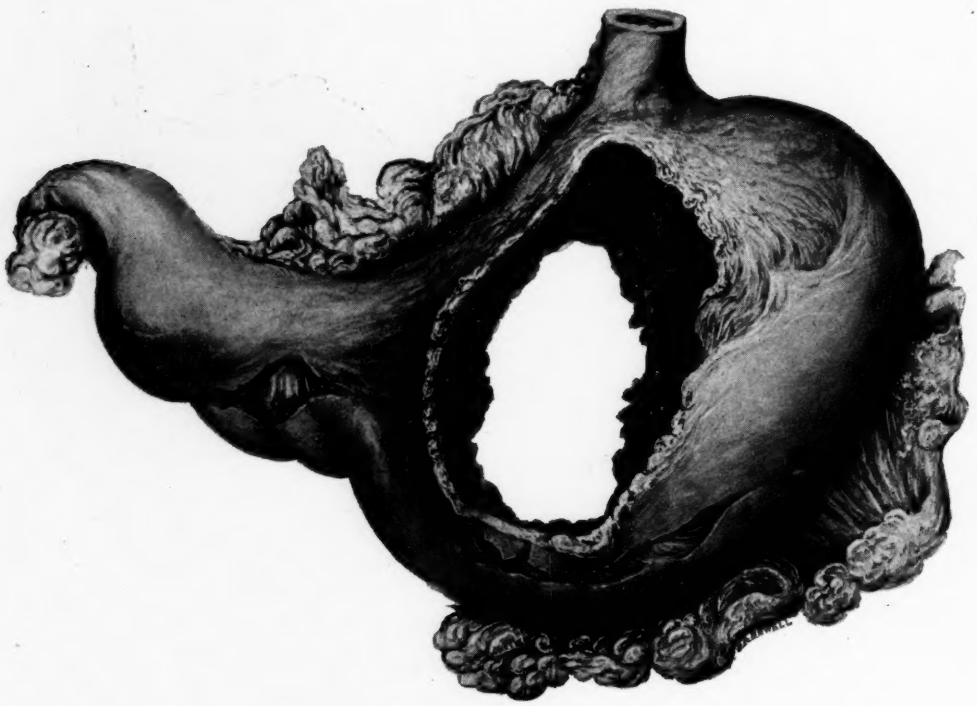

FIG. 7.—The effect of a machine-gun bullet fired at close range.

The bullet was fired at a distance of three yards from the patient's back, causing the explosive effect seen in *Fig.* 7. In spite of the extent of the injury, the man survived for several hours.

Multiple Wounds of the Back and Buttocks. (*Fig.* 8.) (From No. 33 Casualty Clearing Station. Under the care of COL. C. WALLACE.) [*Ref. No.* 121.]

Multiple Bomb Wounds of the Face, Arms, and Legs. (From No. 10 Casualty Clearing Station. Under the care of CAPT. DEW.)

Such bomb wounds are caused by numerous small fragments of thin metal, and are blackened and discoloured by the mud which is scattered with great force by the explosion (*Fig.* 9). [*Ref. No.* 123.]

The wounds are all shallow, but owing to infection by dirt and clothing they are very septic. They often lodge particles of cloth and ragged metal fragments, and they have therefore to be minutely cleaned. Two chief dangers attending them are: (1) Cellulitis, which is especially likely to develop in connection with any wound in which a foreign body has been driven under the skin and lain undetected; (2) Injury to some deep structure owing to the penetration by a metal fragment.

FIG. 8.—DRAWING TO ILLUSTRATE THE NATURE AND APPEARANCE OF THE MULTIPLE WOUNDS INFLICTED BY SHELLS.

FIG. 9.—MULTIPLE BOMB WOUNDS OF THE FACE, ARMS, AND LEGS. THE WOUNDS ARE ALL BLACKENED BY MUD.

FIG. 10.—WOUNDS OF FACE BY A BOMB FROM A TRENCH MORTAR.

Multiple Wounds of the Face from a Trench Mortar Bomb (*Fig.* 10). (From No. 10 Casualty Clearing Station. Under the care of LIEUT. HILTON.)

These wounds are especially liable to be infected, for the reason that as the bomb usually falls to the ground before bursting, it scatters showers of mud in every direction, and plasters it into the wound. The eyes were not seriously injured and the patient did well. Many of these cases are treated at the front with a one per cent solution of picric acid. [*Ref. No.* 120.]

Wound of the Brain by Fragments of a High-explosive Shell. (From No. 25 General Hospital. Under the care of CAPT. R. RANKING.)

Pte. B. was wounded Sept. 27, 1915, and admitted to the base hospital five days later. There was a single entrance wound near the right frontal eminence, and *x*-ray examination showed two fragments of metal lying deeply in the brain on the same side. The patient was drowsy, but could be roused, and would obey simple orders. The neck was stiff. Incontinence of urine and fæces was present. The temperature was 103° and the pulse 80. No paralysis was noted, and both the knee-jerks and plantar reflexes were normal.

FIG. 11.—Shell wound of brain, with fragments embedded.

The edges of the wound were excised. Next day he was brighter, but left facial weakness was present and the left abdominal reflex had disappeared. On Oct. 6 the pulse was 130 and temperature 100°. An operation was done, at which some bone was removed from around the entrance wound; some pus escaped from the brain, and a drainage tube was inserted. On Oct. 10 cerebro-spinal fluid escaped, and death occurred on the following day.

At the post-mortem, basal meningitis was found to be present, as well as the condition shown in the illustration.

Remarks.—Two fragments of metal had entered the lateral ventricle, one becoming embedded in the caudate nucleus. The ependymitis visible to the

naked eye only extended as far as the foreign bodies ; the rest of the ventricular lining was normal in appearance, an unusual and somewhat remarkable condition. The case illustrates what has been so often observed in the present war, namely, the danger of involvement of the lateral ventricle, either in the original wound or by later extension of septic cerebral softening. Few cases in which the ventricle is known to have been wounded, whether actually containing a foreign body or not, have survived. The feature of this case which makes it worthy of record is the limitation of the ependymitis to one part of one ventricle, although the patient survived for a fortnight after being wounded.

Wound of the Liver caused by a Rifle Bullet. (From No. 17 Casualty Clearing Station.)

Fig. 12.—Explosive effect in the liver of bullet fired at close range.

The patient was shot by a rifle bullet fired at short range. It perforated the trunk from before backwards in the region of the right hypochondrium ; he died shortly afterwards from hæmorrhage.

The figure (*Fig.* 12) illustrates well the ' explosive ' action of the bullet tearing open the right lobe of the liver on its exit from that viscus, and leaving multiple radiating fissures running outwards from the centre of injury in all directions.

Bullet Wound of the Thigh. (From No. 17 Casualty Clearing Station. Under the care of CAPT. MEIER.)

A bullet has traversed the front of the thigh from within outwards (*Fig.* 13), severing the greater part of the quadriceps extensor muscle and fracturing the femur (a not uncommon injury). Such a wound presents some difficulty in treatment. The large ragged area exposed is usually infected, and the only way to cleanse it is by cutting through the small bridge of skin

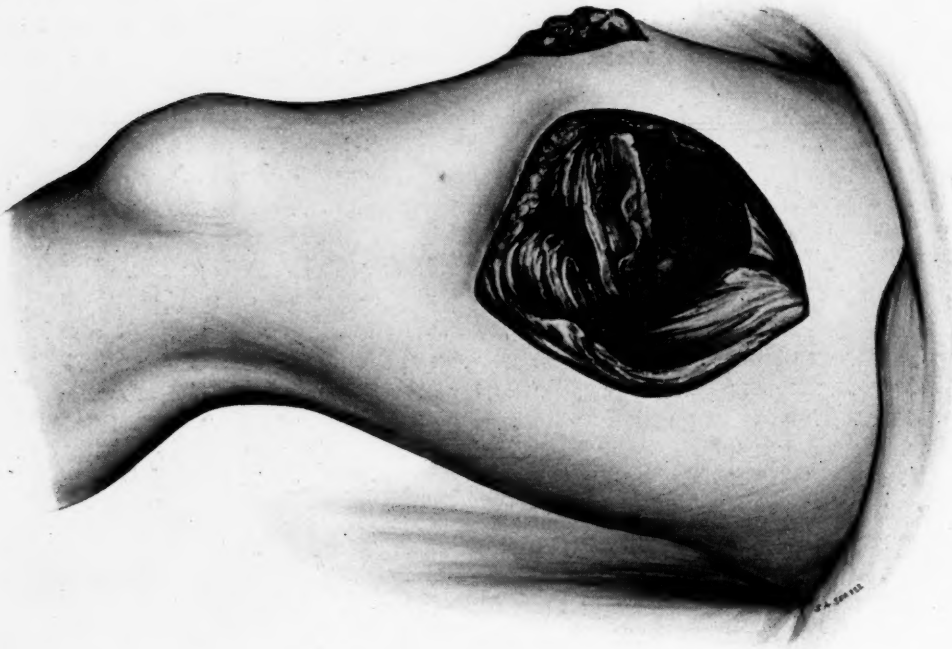

FIG. 13.—Bullet wound of thigh.

between the two wounds, so as to convert the tunnel into one large wound, which gapes widely open, and at the bottom of which the fractured bone will present. But though this seems to be a heroic procedure, it is probably far safer than trusting to mere dressing for drainage and cleansing purposes. If the limb has eventually to be sacrificed, the amputation will be already more than half done, and both the shock and the danger of septic absorption will have been greatly lessened by the preliminary free opening. [*Ref. No.* 124.]

Small Intestine divided in Seven Places by a Rifle Bullet. (From No. 10 Casualty Clearing Station. Under the care of CAPT. DEW.)

The patient presented a single wound in the epigastrium, and his condition rapidly became so serious as to demand operation. On opening the abdomen, the peritoneum was found full of fluid fæcal contents. The central

coils of small intestine had been pierced again and again, and in nearly every instance of the seven distinct lesions the gut had been well-nigh severed, and presented an everted appearance. The missile, which lay loose in the posterior part of the peritoneal cavity, was an ordinary rifle bullet. It is a matter of surprise that this should have had momentum enough to perforate

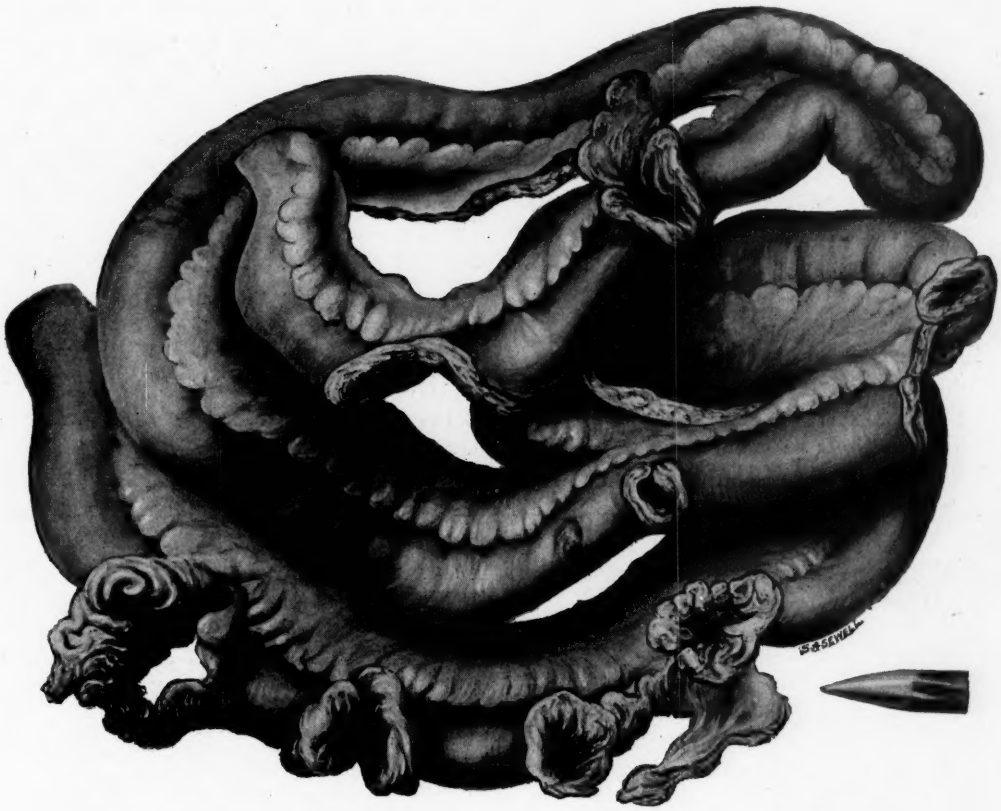

FIG. 14.—Multiple wounds of the small intestine, the effect of a rifle bullet.

the anterior abdominal wall and seven coils of intestine, and yet not enough to make an exit. Possibly the extensive laceration of the gut was due to its having been distended at the time of the wound. The whole injured segment of intestine was resected and the contents restored. The part removed measures between three and four feet. The patient died a few hours later. [*Ref. No.* 122.]

A FEW SUGGESTIONS FOR THE TREATMENT OF FRACTURED JAWS.

By Major A. C. VALADIER, R.A.M.C. (T.H.C.)

The treatment of an ordinary fracture of the jaws, such as we meet in times of peace, is an easy matter for the oral surgeon; but the wounds caused by gunshot, with which we come in contact to-day, require special consideration on the part of the operator.

Wounds caused by bullet or shrapnel will generally be complicated; that is to say, a piece of metal may lodge in a most vital spot. The following points have then to be determined:—

1. Whether or no it is right immediately to attempt the removal of the foreign body.

2. Whether the patient will stand the strain of an anæsthetic.

3. Whether the region of the glottis may be so inflamed as to contra-indicate the use of a general anæsthetic.

4. The patient's oral cavity may be so lacerated that food cannot be introduced. Should he be surgically treated at once to overcome this condition? Or should prosthetic interference for the reduction of his fractured jaw be applied before surgical interference?

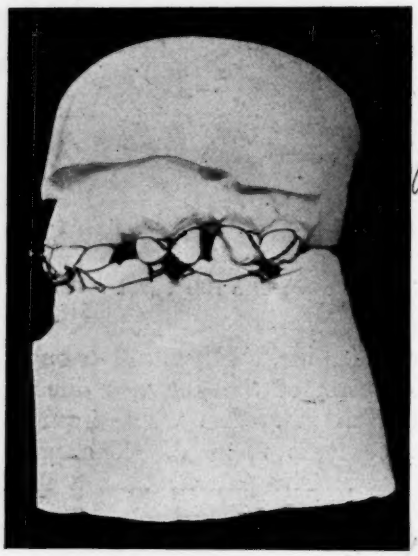

Fig. 15.

These questions are of the utmost importance, and can only be answered by the oral surgeon in charge.

It is not my intention to advise or direct the actions of the surgeon; nor do I claim originality for the different appliances I am about to explain, and which have all been in practical use. Fully appreciating the many valuable articles on this subject which have already been issued, it is with a great deal of diffidence that these notes are given for publication. If, however, the wounded should derive any benefit from my experience, my object will be attained.

Fig. 15 demonstrates how teeth may be ligatured by means of wire. Up to the present time, Angle's No. 25 brass wire has been universally used, but I personally prefer German-silver wire, which I draw down to the same size and thoroughly anneal. Notice how the wiring should be crossed, in order to avoid pulling out the weak teeth from their sockets if a direct pull up and down is tried.

Figs. 16 and 17 are samples of external splints made of vulcanite; the impression is taken with plaster in the hand, in order to obtain pressure where desired.

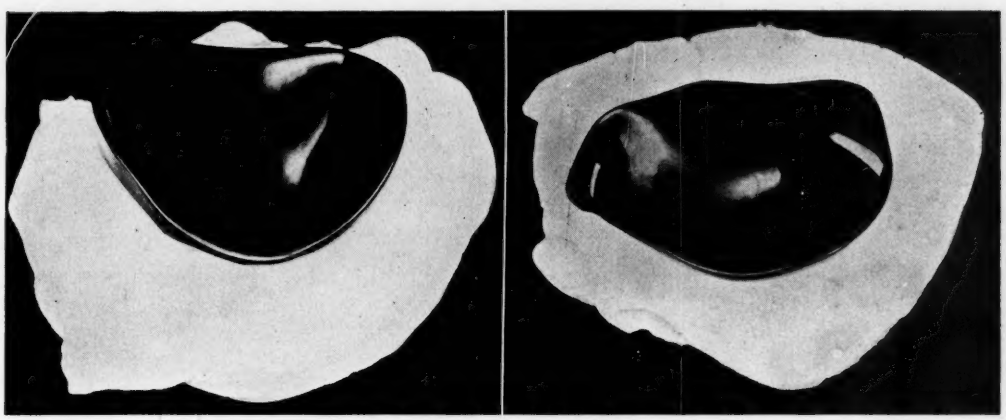

FIG. 16. FIG. 17.

Fig. 18 is a prophylactic splint made of gold or silver wire, to hold teeth in the correct articulated position, as we know that if the teeth articulate properly, the bones cannot be otherwise than in position.

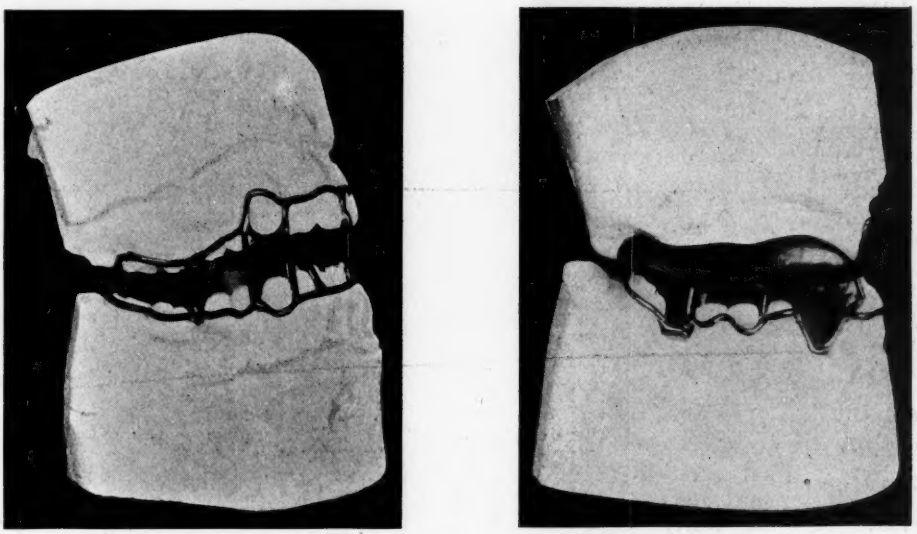

FIG. 18. FIG. 19.

Fig. 19.—A similar splint to suit a case in which the upper jaw is edentulous.

The following two cases are taken together because they are practically alike; in each the lower jaw was shot away completely from second bicuspid

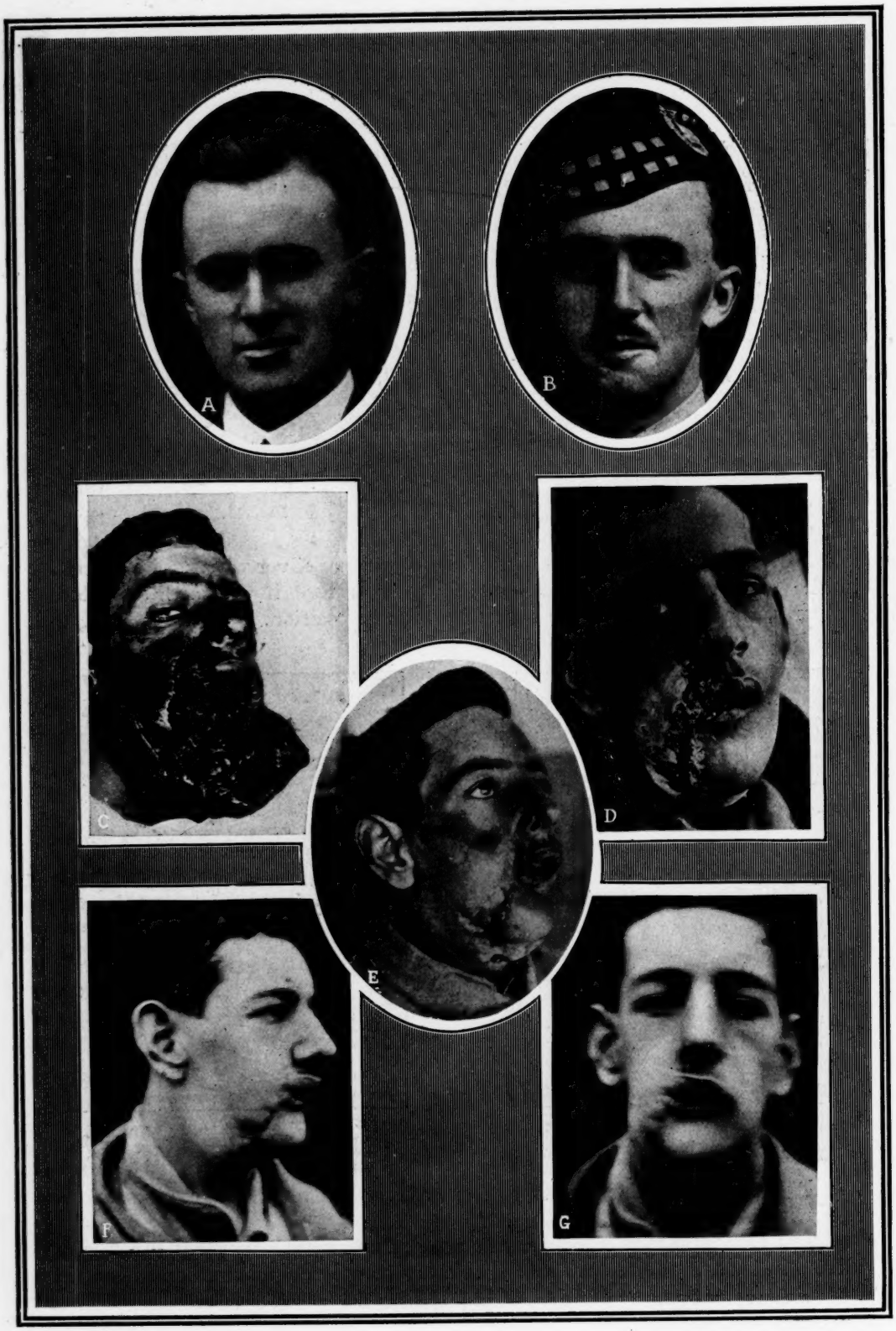

FIG. 20.

to second bicuspid. The first case is that of Sec. Lieut. C., and is practically finished; the second is Pte. H., who is now on the good road to recovery.

Photographs were not allowed to be taken when Lieut. C. was brought to the base, and therefore his original condition cannot be given; but the reader will have to accept my statement, when I say that he was as Pte. H. is seen in *Fig.* 20 c.

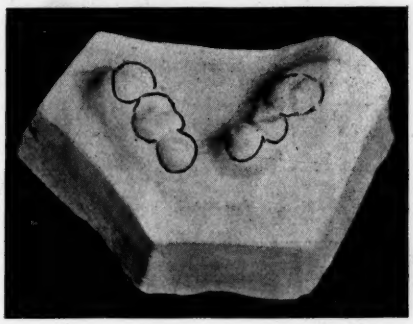

FIG. 21.

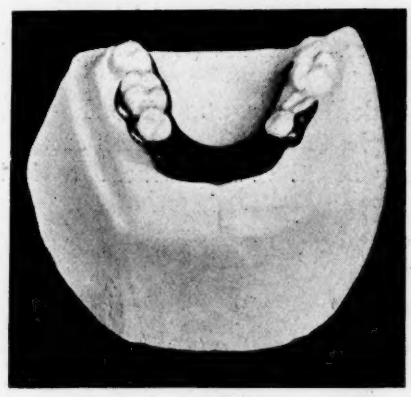

FIG. 22.

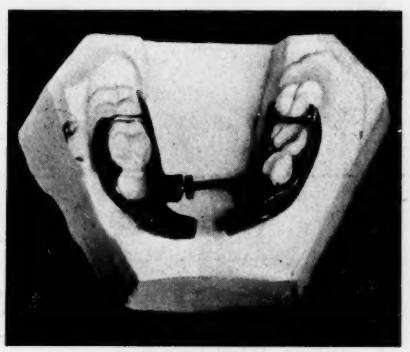

FIG. 23.

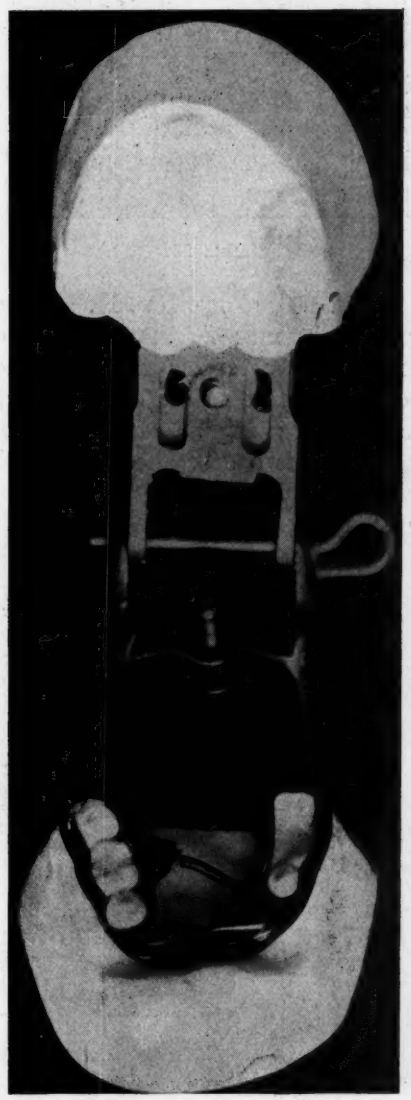

FIG. 24.

Fig. 20 A represents Lieut. C. before the war; notice the protruding lower lip, and that having lost over an inch of lip and chin when wounded, this has

not much interfered with his present appearance. *Fig.* 20 B shows Lieut. C. as he is to-day.

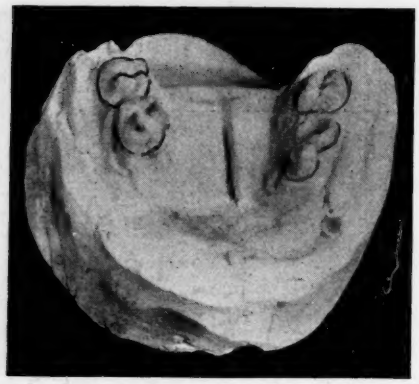

FIG. 25.

FIG. 26.—Callus formation (seven months).

FIG. 27.—Callus now (ten months).

Fig. 20 C shows Pte. H. as when first seen by me; *Fig.* 20 D was taken three weeks after his first operation (performed five or six days after being wounded); *Fig.* 20 E, Pte. H. eight weeks after; *Figs.* 20 F, G, are two photographs taken four months after.

These two cases being alike, I am citing Lieut. C.'s treatment, as it is practically completed.

The two ends of the mandible

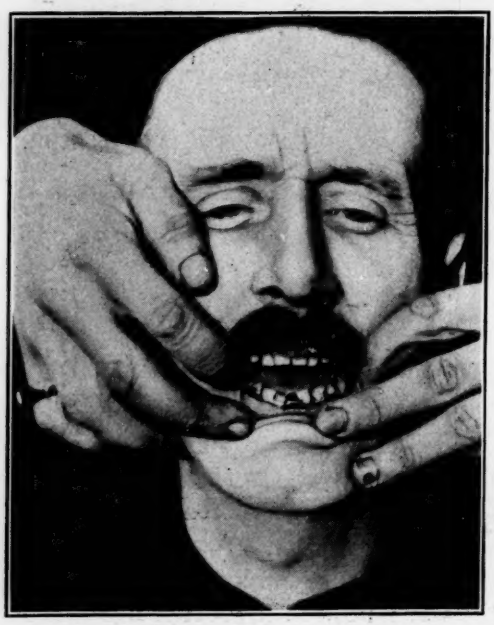

FIG. 29.

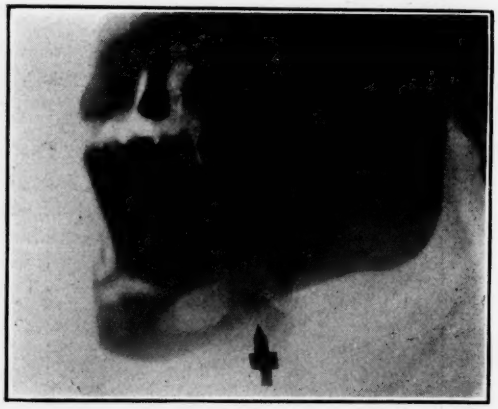

FIG. 28.

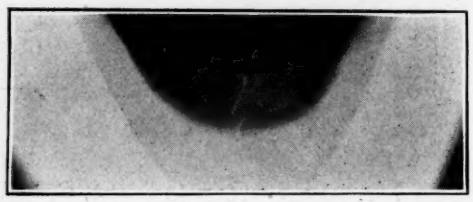

FIG. 30.

were allowed to come together by wiring, and an impression was taken; an *x*-ray examination having shown that callus was forming (*Fig.* 21), a jack-screw was used to push apart slowly the fractured ends (*Fig.* 22), and after four weeks a retention appliance was inserted. Three weeks later a larger jack-screw (*Fig.* 23), was inserted, and this was followed by another, with pressure on a different point (*Fig.* 24) until I had obtained the result as shown in *Fig.* 25. A retention appliance was then inserted to allow for strengthening of callus, which is finally forming new bone, as *Figs.* 26 and 27 show.

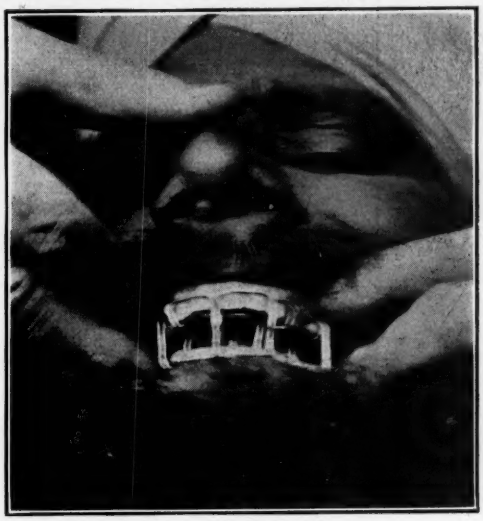

FIG. 31.

Fig. 28 demonstrates a fracture in which the two lower centrals have been extracted for the purposes of drainage; a prophylactic splint was made and an external chin splint applied, in order to push the fractured particles up into position;

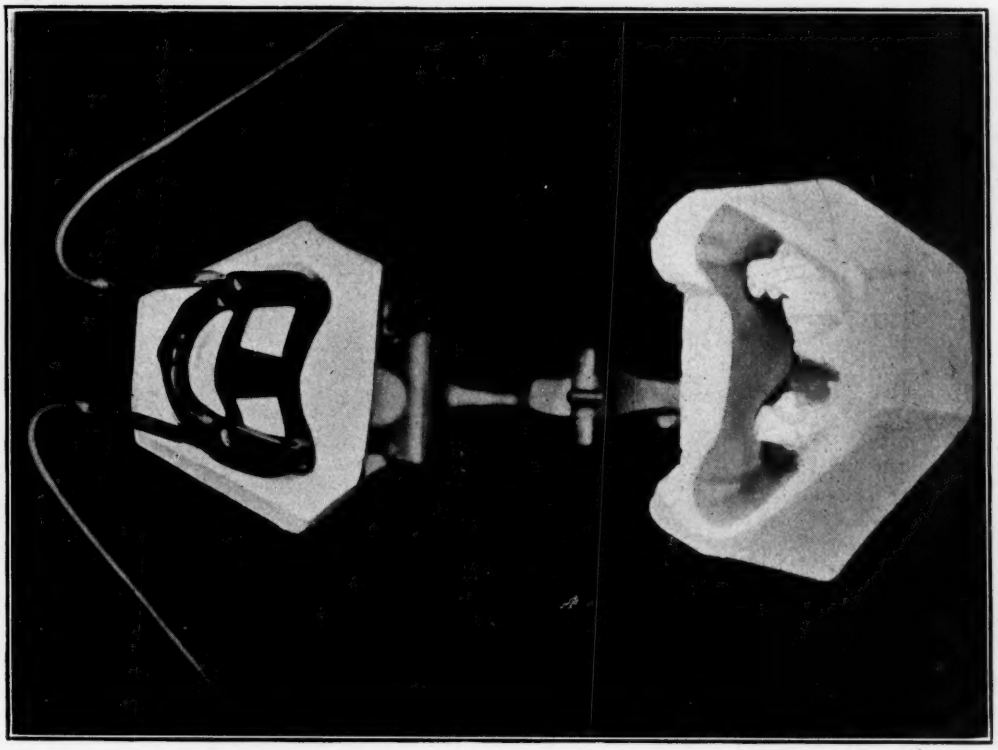

FIG. 32.

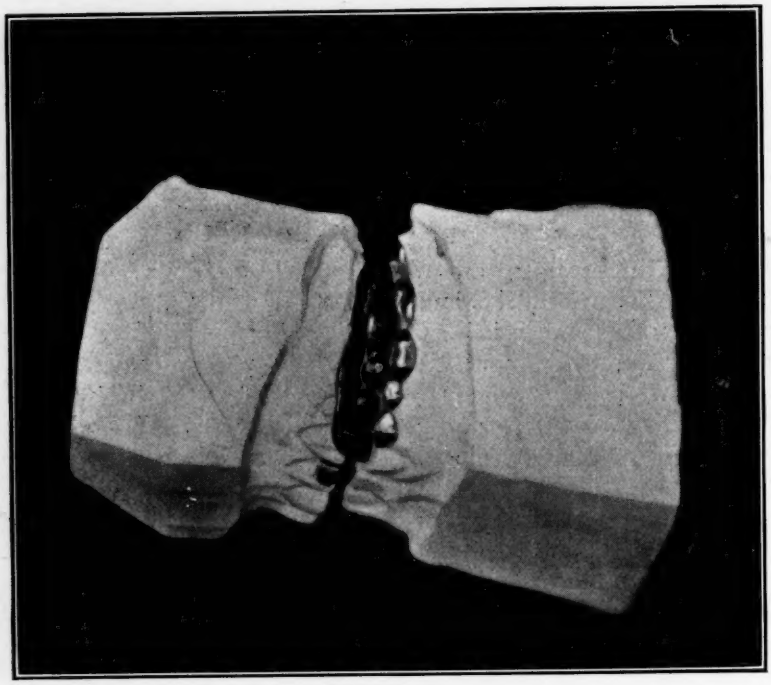

FIG. 34.

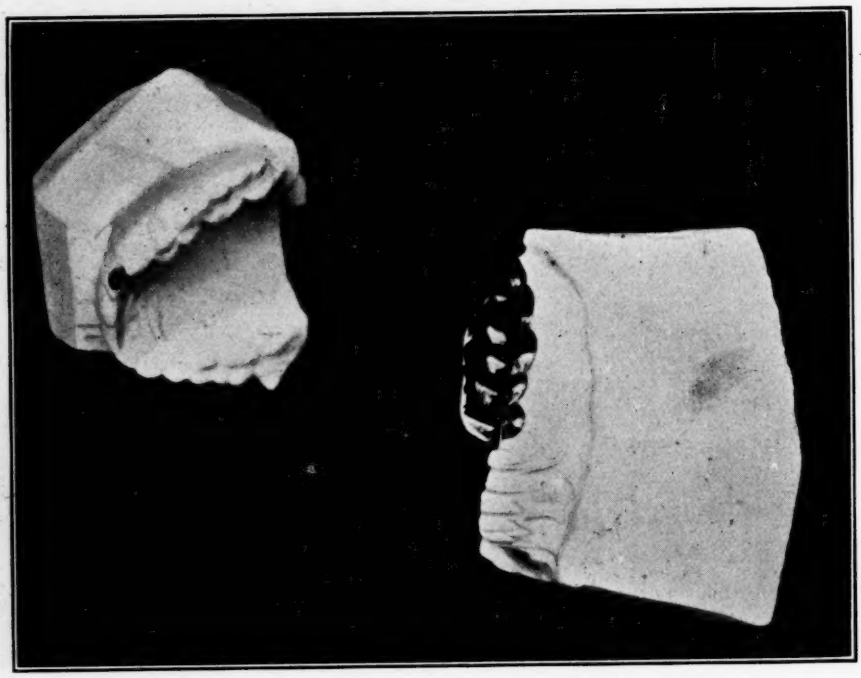

FIG. 33.

in eight weeks the permanent splint was made, as shown in *Fig.* 29, and *Fig.* 30 shows the present perfect position of the bone.

Fig. 31 illustrates the use of a prophylactic splint in the mouth of a wounded Indian.

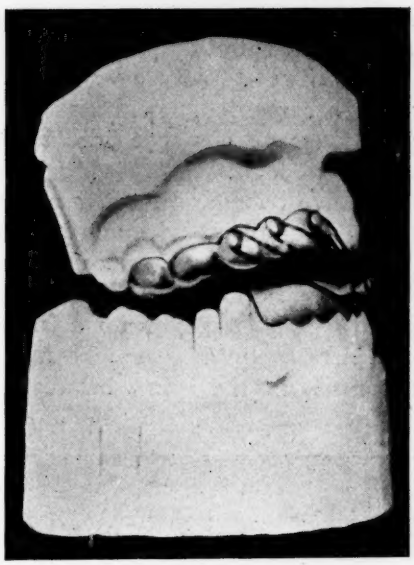

FIG. 35.

FIG. 36.

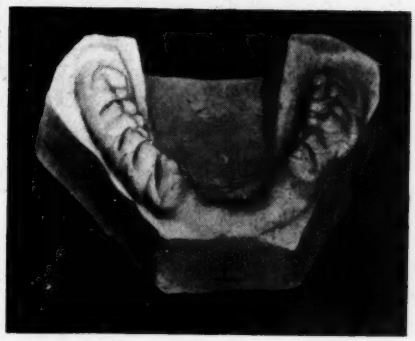

FIG. 37.

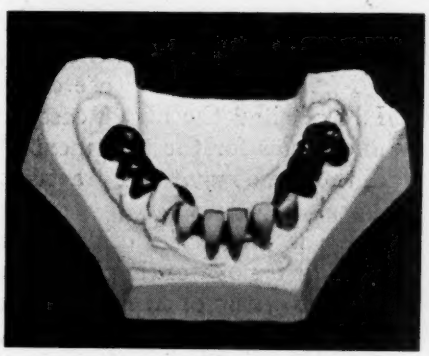

FIG. 38.

Fig. 32 shows a palate splint. The vulcanite plate is perforated for the purpose of cleanliness; there are two square tubes on the sides, in which two metal plungers are inserted, and a large wire goes forward in the vestibule, having its exit at the angles. An adhesive band is placed around the forehead of the patient, and the wire, shaped to fit the cheek, is attached by means of cloth bands at opposite points of contact up to the forehead bands.

Fig. 33 demonstrates a system of inclined plane, made to retain the lower jaw in correct position. The jaw through fracture on the right side was pulled over to the same side to such a degree that articulation was very abnormal; while at the same time disfiguring the patient. Articulation was re-established by means of wiring, and the jaw was held in position by a prophylactic splint; then in order to maintain the accurate position a splint as in *Fig.* 33 was inserted, being cemented to the lower teeth.

Fig. 34 shows the teeth almost closed and the flange on the upper teeth preventing the lower from pushing or being pulled out of position.

Fig. 35 illustrates a fracture of the superior maxilla, from the median line back to the tuberosity on the right side. (When first seen it was almost horizontal to its normal position.) Cast aluminium splints, upper and lower, were made (the lower being included in full because the fracture was anterior to the lower first left molar). They were both cemented, and by means of hooks and Angle's elastic bands, both jaws were readily put into normal position, and the patient was soon able to eat light food.

Fig. 36 shows a fracture of the lower jaw, five teeth and a portion of the jaw being carried away by the bullet; the exit wound was through the floor of the mouth on the right side. Correction was made by means of a jack-screw (*Fig.* 37), and a bridge inserted (*Fig.* 38) as the final result.

Fig. 39 is an example of the elevator cap splint, employed for a fracture at the median line and anterior to first molar. A full splint is cast and cemented to the full lower; several perforations are made in the splint between the

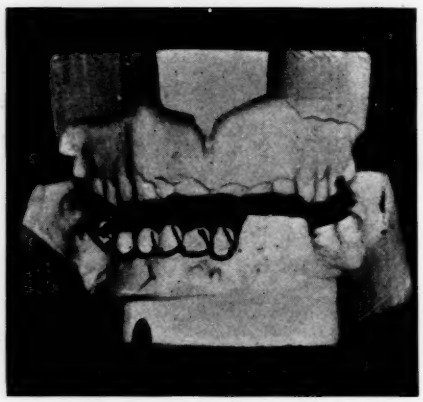

FIG. 39.

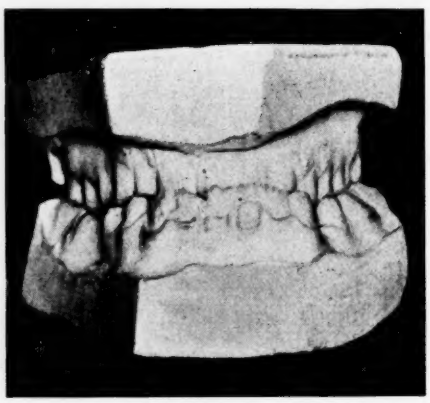

FIG. 40.

fractured points for the purpose of wiring the fractured parts in position; once this splint is inserted the patient can eat almost all foods that are given him. *Fig.* 40 shows the case completed.

I have cited the above cases more to show the possibilities than to give any fixed rules for the treatment of fractures of the jaws. Three men might obtain the same result (the fracture being the same), each one using a different appliance.

The success of the oral surgeon may be much diminished, and in fact ruined, if he is not working in perfect unison with the surgeon who is doing the plastic part of the operation; therefore, unless such an understanding exists, the result will be generally unfavourable.

I have seen this particularly in several instances where I have had the opportunity of treating cases in their later stages; having these patients under my entire care, a comparatively short time was required to render them practically normal.

The general surgeon will not always receive the oral surgeon with open arms; this, perhaps, is a weakness which might be explained if thoroughly examined, but I am convinced by my own experience that though the road may be difficult at first, yet as soon as you have demonstrated your ability, your judgement, and your value, you will be esteemed far beyond your real merit, and will even wonder why, when you have done so little, you should be congratulated by general surgeons far beyond your desires or expectations, receiving scientific recognition more than you deserve.

This paper is but a *résumé* of a few practical cases; I hope to follow it up in the near future with a complete work, comprising my personal experiences in the treatment of fractured jaws, and a more detailed description of the technique and apparatus that I have found of most value.

CONTEMPORARY AMERICAN SURGERY.

By GEORGE W. CRILE, Cleveland, Ohio, U.S.A.

INTRODUCTION.

As far as American surgery is concerned, 1915 was a singularly unproductive year. Perhaps its most important feature was the success of the American College of Surgeons in securing an endowment fund of $500,000 from its members, the income of which is to be used to improve the teaching and practice of surgery. The first task will be the standardization of hospitals, to which end a survey has been proposed.

In surgery of *the head*, fewer excisions of the Gasserian ganglia were made, presumably because of the more general use of alcohol injections. Pituitary surgery for 'neighborhood' symptoms has gained in popularity, the nasal route being the more commonly employed. There have been fewer operations for epilepsy, and surgical intervention for hydrocephalus has been abandoned.

The end-results of *cleft-palate operations* are far from perfect. It would seem that the child should be placed in the hands of a dental surgeon skilled in orthodontia, who can direct the form and growth of the jaw and the teeth, and it is equally necessary for these children to receive special speech training. *Cancer of the mouth* is more commonly attacked with a thermo-cautery—the cauterizations being repeated until all the cancerous tissue is surely included in the destruction. In this manner cancers that have involved the periosteum may be destroyed without excision. Cauterization with a heavy iron causes the necrosis of a layer of bone, which in time is cast off. Combined with such destruction of the primary focus, a block excision of the gland-bearing area of the neck is made. Moderate-sized *nævi* now receive radium treatment. Surgeons as well as internists show a growing recognition of the importance of mouth infection.

Block excision remains the operation of choice in *cancer of the neck*. The operative treatment of exophthalmic *goitre* has gained markedly in favour during the year, and both immediate and end-results are steadily improving. It is now realized that these patients must receive special consideration (*a*) in the preparation for operation; (*b*) by performing the operation by anociation; (*c*) by giving them special supervision for at least one year after operation. It is also appreciated that all focal infections must be eradicated, as imperfection of the tonsils for example. It is now apparent that the so-called 'hyperthyroidism' is chiefly an acute acidosis. For adolescent goitres iodine is almost a specific. It would seem best in goitrous districts to give iodine in advance of the appearance of the adolescent enlargement. The incidence of cancer in fætal adenomata is about eight per cent of all cases coming to operation. Porter's hot-water injection is useful as a part of the graded operation. In advanced cases, the graded operation—hot-water

injections, the ligation of one and later of the other pole, and finally, after perhaps a longer interval, lobectomy—gives excellent results.

In *abdominal surgery*, the revival of surgery of the spleen under the stimulus of the Mayo clinic is perhaps one of the features of the year. The two-stage operation in major operations on the stomach and intestines is on trial; it is certain that under this method the mortality is strikingly reduced, and anociation simplifies the problem. In gall-bladder surgery, excision is practised rather more frequently than formerly. In virulent peritonitis there has been a revival of the opium treatment, which is added to the established surgical treatment.

In *genito-urinary surgery*, suprapubic prostatectomy prevails over prostatectomy by the perineal route. Nephrorrhaphy is rather seldom done. Stone in the kidney is approached through the pelvis, the incision being immediately closed. Silk suturing is avoided in the genito-urinary tract.

In *gynæcological surgery*, operations for uterine displacements are less common than formerly. In the treatment of cancer of the uterus, radium is the first choice in all inoperable cases, and in all cases is a valuable adjunct to surgical measures; in operations, great care is taken to avoid the immediate implantation of the cancer in the fresh tissues. Uterine bleeding appearing at the menopause is most successfully treated with radium—one treatment usually cures. Fibroids are rather successfully treated with radium and with the Coolidge tube: for their removal the suprapubic operation prevails.

Surgery of the bones and joints, and orthopædic surgery, have made no notable departures during the year.

An increasing use of *blood transfusion* is seen everywhere—for hæmorrhage, shock, anæmia, etc., and also for rendering the circulation more stable before surgical operations.

Nitrous oxide-oxygen *anæsthesia* is steadily winning its way, in spite of the technical difficulties and the higher cost of its administration. It is becoming appreciated that nitrous oxide is not only pleasant and innocuous, but that to a demonstrable degree it protects against shock and infection. The interest in *local anæsthesia* is steadily gaining, and the advantages of anociation are becoming increasingly recognized.

American surgeons have seen service with all the warring nations, except possibly in Turkey, the largest interest being in France and England. Those who have had the privilege of such service have profited greatly by the experience.

ANÆSTHESIA—SHOCK—TECHNIQUE.

Duffield[1] has performed 41 operations, largely major, under Crile's anociation, with 2 deaths, neither of which can be attributed directly or indirectly to the operation itself (pulmonary embolism and abscess of the liver). In but six cases was ether given. Only one patient vomited afterwards (morphine idiosyncrasy). Distention was practically absent. The operations were as follows: appendectomy, 10; gall-bladder operations, 2; hernias, 3 (all ether cases); epiplopexy, 1; intestinal obstruction (post-operative after appendectomy), 1; pelvic (female) operations, 7; suprapubic

prostatectomy, 1; vaginal operations, 5; amputation of breast, 2; miscellaneous, 9. It is self-evident that local anæsthesia was chosen in these cases because they were very largely poor operative risks, and in danger of operative shock if general narcosis had been used.

Crile,[2] reporting the results of clinical and laboratory researches, concludes that inhalation anæsthetics cause an increase in the H-ion concentration of the blood. In deep anæsthesia the blood may even become acid. If the blood remains acid for a few minutes only, death follows. The reserve alkalinity is low in exhaustion from infection, extreme shock, starvation, etc. In these states, inhalation anæsthesia must be cautiously administered, and as far as possible local anæsthesia should be used.

Campbell[3] warmly endorses the principle of anociation, the application of which he believes should begin when the patient enters the hospital. He illustrates the value of anociation by the history of a case of diabetic gangrene in a man, age 68, arteriosclerotic, with 5 per cent sugar in the urine. A high amputation above the knee would alone save life, so this was done after the most complete blocking. Pulse before operation 96, after operation 72. Not a bit of shock, not a drachm of blood lost, and the patient returned to bed with unimpaired vitality.

Cases in which, as a prophylactic against post-operative shock, 5 per cent glucose solution to the amount of twelve ounces or so were injected into the rectum immediately after the return of patients from the operating room, are reported by Burnham.[4] In these cases there had been no special indication for this measure, such as acidosis, the injections being considered as much routine practice as is saline infusion. At the same time this procedure could obviate a possible acidosis. When acidosis actually impends, the glucose may be injected before operation. Practically the danger of acidosis for the surgeon is found in cases with post-operative vomiting.

Mann[5] makes an experimental study of shock and hæmorrhage, showing that the clinical signs of shock which appear after section of the abdomen and exposure of the viscera are due to a loss of circulatory fluid, which is not dependent upon any primary impairment of the medullary vasomotor centre, and takes place at a point beyond the control of the vasomotor mechanism. The causes for this loss of fluid are apparently the same as those which determine the accumulation of fluid in any other irritated area and produce the signs of inflammation. The nervous system probably plays no greater part in the former case than in the latter. The condition is made grave when the viscera are exposed, because of the great vascularity of the tissues involved.

The numerous theories as to the causation of gas pains and the mechanisms involved, as well as various plans for relieving the patient, are discussed by Dickinson,[6] who finds nothing equal to Kemp's tube. When the choice of method is left to internes and nurses, they invariably resort to that apparatus. Others use pituitrin, the milk and molasses purgative enema, etc. The dread of gas pains deters many subjects from second operations.

Brewer[7] attempts to give the percentage of clean cases of surgery which became infected during stated periods at the Roosevelt Hospital. From January to July, 1912, this percentage was 2·4, and for the balance of the year 1·2. In the first and second halves of 1913 the figures were 1·8 and 1·6

respectively. From January to July, 1914, this percentage in 273 clean operative cases was 0. The figures given are all gross totals. If certain cases of infection for which the operating staff could in no way be responsible are subtracted, the percentage in the 516 cases last recorded would be 0·2.

SURGERY OF THE BONES AND JOINTS.

The uniform success of Albee[8] has proved that a *bone-graft* is a trustworthy agent, for he has used it in over 350 surgical cases. He has also proved its success by careful study, "microscopically, macroscopically and by the Röntgen rays, of its results, when used experimentally, both in the presence of primary union and sepsis. The cortical graft's field of usefulness is distinctly enhanced because of its resistance to tuberculous and attenuated pyogenic infection. Its field is also enlarged by the use of the author's motor-driven instruments, circular saws of different sizes, the adjustable twin saws, and the lathe or dowel instruments with different adjustments for making the various sizes of bone-graft inlays, nails, or spikes as they are needed." He adds that he has been able to avoid the use of metal fixation of any kind. Other fundamental resources include the use of kangaroo tendon. He calls attention to the fact that his work is patterned largely after the resources of the wood-joiner—inlays, wedges, dowels, tongue and groove joints, mortised and dovetail joints.

Scudder[9] enunciates seven fundamental principles in the *operative treatment of fractures*: (1) The most nearly perfect adaptation of the fractured ends; (2) Operation when performed must be done early; (3) With advancing age prognosis in non-operative treatment becomes less favourable; (4) In childhood, operation and expectancy give the same percentage of good results; (5) The mortality in operative cases is negligible; (6) Operation prevents a number of untoward by-effects; (7) Operation is most indicated when most available—i.e., if a surgeon is a master of non-operative technique, and operation is not fully practicable, he should select the former; while in cases in which operation is both available and ideal, he should operate.

The Hibbs *osteoplastic operation for Pott's disease*, first published in 1911, and again in 1912, has been used for 158 patients to date. Farrell,[10] in a study of this material, finds 7 deaths, and 4 patients requiring re-operation. In every other case, save 3 who came to the clinic with paraplegia, the functional results have been excellent, all symptoms having disappeared except the gibbosity itself. None wears any apparatus, and all are able to carry out the ordinary avocations of life, whether work or play.

Allison and Moody[11] give case histories, with *x*-ray photographs, of eleven cases of *osteochondritis deformans juvenilis* (Perthes' disease). They believe that the disease is a disturbance of the line of epiphyseal growth. Some animal experiments threw no light on the affection. In the discussion, Dr. Legg, who has treated 55 cases, stated his belief in a traumatic causation (history in 67 per cent, great preponderance in boys); Dr. Ridlon thought the disease not an entity, and that coxa vara, bone cysts (osteitis fibrosa) and other affections had been included in the material. Others thought tuberculosis had not been sufficiently excluded. There should be a reaction in

the joint itself. If it is purely a nutritional disturbance of the joint, pituitrin should be tested.

Flat-foot is natural in some feet, says Lovett,[12] and does not represent a fallen arch or a congenital deformity. Any shape of foot may become painful from foot strain, and a high arch under the circumstances does not give way. Since boots cramp the feet and do not adequately support the sole, the high arch is more apt to suffer from foot strain than is the low arch. When the foot has become strained, a metal support should be used to rest it. Painful feet are more helped by raising than by lowering the heels.

A study of *tuberculosis in the knee-joint* in childhood, by Sever and Fiske,[13] is based on 638 cases, of which 380 occurred in boys. In 30 per cent there was a history of trauma, and in but 13·5 per cent a family history of tuberculosis. Osteal involvement predominated. Thirty-five per cent were operated on by nine different operative procedures; the average duration of treatment in these cases was 5·8 years. Cases treated without operation were under treatment for but 4·2 years on the average. Judging by the three-year limit, results were satisfactory in 65 per cent of all cases.

Boehme,[14] a neurologist, describes an apparently new occupational disease, *chauffeur's knee*. The subjects have pain in the knee when they ascend stairs or use the pedals of the machine. Flexion is limited and painful, extension likewise, and there is a grating in the joint. The right knee is usually the one involved. There is a fluctuating swelling on either side of the patella, and in general the condition resembles subtendinous bursitis (the bursa which lies between the patella and expansion of the fascia of the quadriceps). The chauffeur flexes and extends the joints, as he controls the gas and other pedals, with his knees somewhat cramped. In this way a low grade of bursitis is set up. In theory there should be a similar condition at the ankle joint (tenosynovitis). The treatment is general—rest, embrocations, and, later, passive movements, massage, and baking.

Skillern[15] has analyzed 100 cases of *fracture of both radius and ulna in childhood*, 81 of which occurred in males. An exhaustive analysis leads to the following conclusions: This fracture makes up about 70 per cent of all fractures of the forearm in childhood. Injuries to epiphyses should be recognized and treated as fractures because of their importance in the growth of the bones. In the diagnosis the *x* rays are of value for corroboration only. If deformity is actually present, further examination should be cut short. The tenderness felt is of the wincing kind. A fracture is far more likely to occur in this site than a contusion or sprain. Deformity calls for an anæsthetic; otherwise splint and pad without it. If operation becomes the indication, Albee's inlay method is recommended.

In connection with an account of an *excision of the scapula for osteosarcoma*, Murphy[16] introduces a table of 797 cases of sarcoma of the bone recently compiled from a number of sources. In only 23 cases was the scapula the site of the tumour. The principal locations in order are as follows: jaw, 227; femur, 160; tibia, 100; humerus, 90; radius, 40; etc. This list, of course, is not exhaustive; it simply shows the relative incidence.

DISEASES OF THE BREAST.

Bunts[17] advocates conservative operations for *cysts* of the breasts. He reports for himself and for his associates, Drs. Crile and Lower, that they have notes of 648 breast operations, of which 68, or more than 10 per cent, were for cysts. Subsequent histories were obtained from 55, showing that in no case had cancer developed.

In Rodman's[18] series of 50 consecutive private cases of *cancer of the breast*, 36 (or 72 per cent) have survived the three-year limit, and 24 the five-year limit. The author denies that his material is especially selected. The mortality of extirpation of the breast should not exceed ½ per cent.

SURGERY OF THE CHEST AND ORGANS OF RESPIRATION.

Shambaugh and Lewis[19] discuss with thoroughness cases of *laryngeal diverticula* reported by others—although no attempt is made to analyze the entire literature—and they report a case of combined intra- and extra-laryngeal diverticulum. They arrive at a number of conclusions: The sudden formation and early age at which these diverticula appear suggests a congenital origin, and they may be analogous to the lateral air sacs in howling monkeys. True diverticula occur constantly in the same localities, and may be extra- or intralaryngeal, or combined. The external variety, as a rule, is easily removed, as the usually small pedicle is not prolonged into the larynx. The intralaryngeal and combined forms cannot be treated through the lateral passages, and it may be necessary to perform laryngofissure in order that the diverticulum can be successfully enucleated.

A new method of treating *empyema* has been used by Lilienthal[20] in 23 cases. He mobilizes the lung before firm adhesions form. Regarding rib resection as uncalled for, he makes a long incision and, using rib spreaders, explores the pleural cavity, noting the presence or absence of foci of suppuration, etc. The spread ribs are left in their position, and the space suffices for drainage as long as it is necessary, by which time they will have returned to their natural positions.

SURGERY OF THE HEART AND VASCULAR SYSTEM.

As a result of a study of collateral circulation by means of intravascular injections and the *x* rays, Stetten[21] concludes that *arterio-venous anastomosis* is futile in the treatment of impending gangrene of the lower extremity. For injection, red oxide of lead emulsified in paraffin oil was used, while the material consisted of human limbs amputated in the course of the thigh for diabetic and senile gangrene, thrombo-angiitis obliterans, etc. Of 136 of these cases, the operative mortality was over 30 per cent, while the alleged successes numbered 24, of whom 8 succumbed not long after operation, making 16 recoveries, a percentage of 11 per cent. Even in the latter cases the author is not satisfied that the operation was responsible for the recovery. The anastomosis may function, but there is no real improvement in the circulation. The arterial disease is in every way better than a retrograde venous circulation.

Hodge and Sweet[22] report a case of *arterio-venous aneurysm of the femoral artery and vein*, which appeared for treatment fourteen years after the traumatism, a bullet wound involving both vessels. Despite the arterial wound, the patient made an apparent recovery with only a simple occlusive dressing. The point was strongly made that long-diseased vessels could not be sutured like sound vessels, for the exceedingly fine sutures are apt to cut through, and primary or secondary hæmorrhage results. In this case the two vessels were isolated and found to be much dilated, especially the vein. They had been adherent for one and a half inches, the actual opening being three-fourths of an inch. This channel was clamped and closed with a row of fine silk interrupted through-and-through sutures. The last suture cut through, necessitating another. The patient made a good recovery.

An interesting case of *end-to-end anastomosis of the axillary artery* is reported by Grant,[23] making a total of seven cases on record. The first method tested was invagination, this being supplanted later by anastomosis. In one case there was a transplantation of a piece of vein into the artery. Grant's case was an attempted suicide. The edges of the vessel were approximated by the overhand Carrel suture. After operation there was no pulse in the brachial or radial arteries. The latter began to pulsate permanently six weeks later.

Murphy[24] has never seen a case of *thrombo-angiitis obliterans* except in a Jew. He describes a case in which he performed three amputations in the right lower extremity. The first was above the ankle for gangrene of the foot. The stump was tender, and so painful that a second amputation was made, but still an attempt to wear an artificial leg proved unsuccessful, and the knee became ankylosed and flexed as he lay in bed. Tenotomy was performed, the knee was straightened, and a third amputation was made two inches above the end of the stump, the nerve stump being split and half of it turned back, while the rest was amputated to prevent painful stump and neuroma. If this operation fails, section of the posterior nerve roots in the sacral spine will be indicated. The author has seen bilateral thrombo-angiitis obliterans obstructing the renal artery exactly simulate renal colic. In this case there was complete anuria, and in decorticating the supposedly sound kidney it was found to be bloodless, as was its fellow at autopsy.

SURGERY OF THE HEAD AND SPINE.

Grey[25] takes, as the basis of a study of the localization of *cerebellar tumours*, the material from Cushing's clinics in Baltimore and Boston. The main point for determination is the presence or absence of pre-operative nystagmus. Among the 51 verified subtentorial growths were 34 cases of cerebellar tumour proper and 17 extracerebellar growths. In the former series, 11 cases—about one-third—had no nystagmus previous to operation. It would appear therefore that the cerebellar syndrome without nystagmus would indicate the presence of an intracerebellar tumour.

Garnett[26] adds 4 cases of *typhoid spine* to over 100 already on record. Of the total, but 30 had been skiagraphed, so that the radiograms of 3 of the author's cases increase the number materially. Some *x*-ray examinations have

given negative results, and he therefore employs Pancoast's lateral method in addition to the anteroposterior. In treatment, the chief reliance should be placed on immobilization.

Church[27] analyzes the *mental symptoms following cranial injuries.* In 2220 cases of insanity, nearly 3 per cent had a history of alleged injury of the head. Of 9000 cranial injuries to German troops in 1870, only 0·144 per cent developed insanity. Since then there have been cases of transitory mental disturbance following cranial injuries. In other words, the general prognosis of these mental disorders is good, very few ending in hopeless insanity.

In his study of the *results of operations for brain tumour,* Cushing[28] has considered all brain tumours, and the results of a number of brain surgeons. Only in recent years have large figures been available. Tooth has reported 265 cases, von Eiselsberg 168, Krause 109, Kuttner 104, and the author 476—334 at Baltimore and 142 at Boston. Mass statistics lead to no result. The author endeavours to form groups, and in various ways to standardize the subject. Thus, in the case of cerebello-pontine tumours, figures from three foreign clinics show an operative mortality of 72·7 per cent in 77 cases. Against these, the author has to offer 13 cases in which diagnosis was reached indirectly, and decompression was the only intervention; none of these cases ended fatally. Including both series, the mortality was but 13 per cent.

In part under the direction of Frazier, Moore[29] has prepared a paper on a case of *fracture of the base of the skull.* The patient was an epileptic boy of six, who fell backward downstairs. Bloody fluids soon began to flow from the left ear. He lived about two weeks. Autopsy showed no lesions to account for death. The amount of secretion which had escaped from the ear was enormous when we consider that 100 c.c. is the normal quantity of cerebrospinal fluid in adults. In health this amount is not exceeded because, when a certain pressure is reached, the secretory process in the choroid plexus is arrested, an example of physiological adaptation. Adrenalin reduced the secretion by one half, as did likewise atropine, but the precise mechanism was not apparent. The action was brief. The fatal ending was doubtless due to the excessive loss of fluid, due in turn to an abnormal brain, epilepsy being one symptom of the latter.

Pain and sensory disturbances in diseases of the spinal cord may be felt in various localities, the lower extremities and abdomen chiefly. Whatever the cause, Elsberg[30] believes it is sometimes necessary to divide the posterior spinal root which corresponds to the painful areas. Often the subsidence of puzzling pains has followed craniectomy for tumours of the spine. Twice he has operated for peripheral pain due to malignant metastatic tumours of the spine by the method inaugurated by Spiller and Martin, which consists of division of the anterolateral columns of the cord. This resource may come to supplant simple division of the posterior roots, which is rather a palliative than a radical procedure.

ABDOMINAL SURGERY.

Porter[31] selects the term *leather-bottle stomach* as the one that best describes a certain affection or affections of the stomach to which twenty different names have been applied. Many of these terms suggest an

interstitial inflammation with following sclerosis of the organ; but various individual processes may be comprised, as cardiovascular and precancerous lesions, cancer, etc. Of 67 cases on record, the author enumerates 39 benign and 28 malignant. The process in either type of case may be rapid, beginning perhaps in the midst of health. In a patient of the author's, the entire stomach was involved in five weeks. Gastrectomy gave temporary relief, but the growth was found to be cancerous. 'Recoveries' from inoperable cancer as a result of gastro-enterostomy may have been cases of benign leather-bottle stomach.

Smithies gives an analysis of 712 consecutive cases operatively and pathologically proved to be *gastric cancer*. The ratio of male to female was about two to one. The age of the youngest patient was 20. In about 2 per cent of the cases there were no symptoms. 'Early diagnosis' usually means good guessing. In 61 per cent there was a long history—averaging 11 or 12 years—of antecedent gastric disorder, chiefly suggesting gastric ulcer. The symptoms pointing to subsequent cancer had been present on an average for about six months. In 31 per cent of the cases the condition began outright with symptoms which suggested malignancy. In 5·5 per cent cancer was 'primary' as far as the stomach symptoms went, but the patients complained of the appendix, gall-bladder, colon, etc. The first or largest class should hold out some hope of surgical cure, but we have no means of foreseeing what a gastric ulcer will do, because of the strong individualization in these lesions.

Woolsey[32] reports that within the last few years he has operated on 36 cases of cancer of the stomach, in 30 of which the pylorus was involved. They were mostly advanced cases, i.e., late diagnoses. Resection was of course the only curative operation. Out of 13 cases in which resection was performed, only one died as a result of the operation. The ultimate results, however, were not so good, and no real survivals are mentioned. The author has performed 10 gastro-enterostomies, and is not satisfied with this operation, as no marked measure of relief is obtained. Five gastrostomies were done for cancer of the cardia. There was a single case of jejunostomy, while the balance were merely explorations.

Finney and Friedenwald[33] compare the results of 100 cases of *gastro-enterostomy* in their own work with the same number of cases of pyloroplasty, reported about a year ago. The end-results of gastro-enterostomy were satisfactory in 77·2 per cent; in pyloroplasty in 88·6 per cent. The mortality in the former series was seven cases, in the latter five. Hence, both the immediate and end-results are somewhat superior in the pyloroplasty series. Gastro-enterostomy is the operation of choice in cases in which by reason of adhesions the duodenum cannot be mobilized, and when ulceration is hypertrophic; these conditions are, however, rare. Gastro-enterostomy, again, cannot be associated with the excision of ulcers. In cancer, gastro-enterostomy has a distinct field as a palliative resource.

Graham,[34] in his notes on *gastric and duodenal ulcers*, deals chiefly with the diagnosis, basing his figures on the 1300 cases of duodenal ulcer and 451 of gastric ulcer at the Mayo clinic from 1906 onwards to the present year. Duodenal ulcer was originally 'missed' in no less than 46 per cent of the cases, and gastric ulcer in 45 per cent. In the great majority of diagnostic errors,

the two forms of ulcer were confounded with each other. In 175 cases of duodenal and 40 of gastric ulcer the clinical diagnosis was gall-bladder disease. A wrong diagnosis of appendicitis was made for 64 cases of duodenal and 8 cases of gastric ulcer. Gastric ulcer was diagnosed as cancer in 22 cases. The author analyzes the pain-and-tenderness symptom with great thoroughness. In about 50 per cent of both types of ulcer these are located at the epigastrium. Pain most frequently radiated to the back. Vomiting was present in about 80 per cent. Complaint of gas was seldom absent in cases of duodenal ulcer. As is evident from the high percentage of mistaken diagnoses, characteristic or very suggestive symptoms are not marked. More than one-fourth of the cases were perforative.

Walker[35] finds 78 cases of acute perforation of ulcers of the stomach in the records of the Boston City Hospital, 1905-1914. The technique of the 17 operating surgeons was uniform, as were likewise the results. The proportion of male to female was twelve to one, while two-thirds of all patients gave an alcoholic history. The duodenum was the site of 36 perforations, the stomach of 42. In nearly every case some history of local mischief preceded the rupture. The operative mortality was 26·9 per cent, in spite of the fact that most of the patients were poor operative risks. The shorter the interval the better the prognosis, as evidenced by the fact that the ten operations performed within the first four hours after perforation gave no mortality, while there was a mortality of 17·9 per cent in those performed in from five to twelve hours after perforation.

Brewer and Cole[36] have introduced an entirely new technique for the diagnosis of surgical lesions of the stomach and intestines. While, according to the 27 case histories reported, this method seems far superior to any heretofore proposed, it requires too much time and expense for it to come into common use. Possibly a simpler method may be made to give as good results. The method of serial Röntgenography employed is carried out by a Röntgen cinematograph, this idea having already been utilized by physiologists in the study of gastric motility. With their apparatus the authors have made 200 serial plates of a total peristaltic wave. Any pathological alteration is made manifest by defects in the plates, and even minute lesions cannot escape detection. A normal stomach is readily recognized. The *x*-ray diagnosis was used for the standard test, and other methods for corroboration only.

During the past five years Peck[37] and his colleagues have operated on 120 patients for non-malignant ulcers, nearly three-fourths of which were seated in the duodenum. Of the 17 cases of acute perforation of the duodenum included in this number, 2 were lost by operation and 2 others probably died as an indirect result of the intervention. Of the 13 gastric perforations, 6 were lost by operation, although in four of these cases the peritonitis, which was the direct cause of death in all, was present before operation. The number of chronic gastric ulcers is too small to be useful statistically, but the 71 chronic duodenal ulcers were all treated by gastro-enterostomy, with 6 operative deaths. The author's experience with gastric analysis as a diagnostic measure is not favourable, but he is a warm partisan of *x*-ray examinations.

Redman[38] is opposed to gastro-enterostomy in cases of ulcer in the

ulcer-bearing area, provided the pylorus and continuous duodenum can be mobilized, for the mortalities of excision and pylorectomy are but slightly higher. If the pylorus is hopelessly adherent, a gastro-enterostomy must be performed midway in the stomach, in order that pylorectomy may be done later. This latter operation may be done in two stages in inferior risks. Ulcers away from the pyloric end should be resected, or a partial gastrectomy done. The mortality in this locality is smaller than that following gastro-enterostomy, although the author gives no statistics.

Eusterman[39] reviews 37 cases of *hour-glass stomach* from benign ulcer, from the records of the Mayo clinic, 1907–1913. Of these, 24 were in women, and perforation occurred in 16; in all cases operation was performed; in all, pain was present, though varying much in character; and in 80 per cent the ulcer syndrome was seen. In addition to these ulcer cases, there were 8 cases of malignant and 3 of luetic hour-glass stomach. A great variety of operations were performed: gastro-gastrostomies, 10; posterior gastro-enterostomy, 8; Hartmann's gastroplasty, 5; and combined operations, 8. The author also notes 8 cases of hour-glass duodenum (6 in males), each with the typical syndrome, and in all cases but one marked pyloric obstruction was present. In 7 cases posterior gastro-enterostomy was performed, operation in this case consisting of excision and plastic enlargement. Neither immediate nor end-results are given.

Bartlett[40] reports an experimental study in *exclusion (functional) of the pyloric antrum*, in which ten experiments showed that almost any operation which removes a cuff of mucosa and submucosa, with approximation of the denuded muscular coats, results in the formation of a diaphragm. These operations are not admissible on the human subject. He feels that his two methods of incomplete exclusion, reported in 1914, can accomplish as much as the more difficult Doyen–von Eiselsberg procedure, for with the former no prolapse of the major portion of the stomach is possible. Whatever the technique, the pyloric antrum undergoes a surprising diminution in size after partial exclusion, this result being due perhaps to tonic muscular contraction.

McKenna[41] reports a case of *intragastric adhesion*, which in a radiograph appeared to be a typical hour-glass stomach. In the course of excision of the ulcer in the lesser curvature, there was found a tongue or band of mucous membrane extending from the floor of the ulcer proper to the opposite side of the stomach. The ulcer, indurated and saddle-shaped, had caused but a slight degree of contraction in the diameter of the stomach. Such conditions may be overlooked in radiograms, or may be wrongly interpreted.

W. J. Mayo[42] calls attention to the remarkable inversion of his percentages, during the past decade or more, in regard to the relative frequency of gastric and duodenal ulcers. In 1904 he had 27 cases of gastric and 27 of duodenal ulcer, as against 27 gastric to 73 duodenal in 1914. In Germany the same inversion has recently been noted. The one explanation possible is that until recently duodenal ulcers have been habitually overlooked. At present our means of diagnosis are the history, the *x*-ray findings, and the physical examination. With the aid of the first two alone the diagnosis can be made in 95 per cent of all cases, although it is quite evident that neither of these two resources was available until recently. The symptom-

complex now recognized as typical for these lesions was formerly interpreted to mean one of a number of other conditions. Our knowledge went hand-in-hand with the revelations of operations.

Campbell,[43] in reporting a case of *benign tumour of the stomach*, claims to be the first to remove a papilloma of the stomach after a definite medical diagnosis. The patient, a woman of 51, had suffered intermittently with severe digestive disorder and loss of weight for two years. Findings were negative, save for achlorhydria; there was no pyloric obstruction; later, however, a little latent blood was found in the stools and stomach contents. A pathologist suggested benign papilloma, although the surgeons believed the condition betokened either cancer or ulcer. After a laparotomy failed to clear up the obscurity, diagnostic gastrostomy revealed a papillomatous growth as large as a pigeon's egg, which was easily freed at its pedicle. Nine months later the woman was free from symptoms.

Matas[44] reports a case of *hair ball* or hair cast of the stomach, making the total number of known cases 77, including six where they were found in the small intestine. Of the total number, 48 were treated by operation, gastrostomy being performed in 44 cases, including the author's; in the other 4 cases, the intestinal location required an enterotomy or resection. There were 2 operative deaths. In 8 cases the diagnosis had been made by the *x* rays before operative intervention.

Carson and Smith[45] make a compilation of 9 cases of *primary sarcoma of the gall-bladder*, adding 1 case to the list made last year by Iwaski. There is no predominant type, round- and spindle-celled growths being represented along with myosarcoma, although polymorphism is a characteristic feature in most cases. Not only are round and spindle cells found together in individual growths, but smooth muscle, giant cells, calcified tissue, cartilage, and bone are present at times. As these tumours, in growing from the inner aspect of the gall-bladder, are likely to obstruct the duct, stone is a common complication, although the pre-existence of the latter is not readily excluded.

Deaver[46] makes a review of 159 cases of *gall-stone disease* operated during 1914, of which 87 were simple cholecystitis, 20 cholecystitis with common-duct implication, and 52 cholecystitis with pancreatic involvement; of this total, 7 were re-operations. The total mortality was 6·3 per cent, the high figure being due to the large number of pancreatic cases, the mortality for this series alone being 9 per cent, while the mortality for the other classes was 4·5 per cent. In 70 per cent of all cases stone was present. The *x* rays were not very helpful in diagnosis; in fact, the use of the *x* rays in these cases is dangerous, since it makes the presence of stone the pivotal point in the disease, whereas it is only a late complication or effect of it.

Buchanan[47] reports a series of 300 operations on the gall-bladder, in which the mortality was 4·66 per cent. He performed drainage operations in 95 per cent of his cases, excision in 5 per cent. He feels that cholecystotomy is not a satisfactory operation, since there are only 81·7 per cent of ultimate cures in unselected cases. Cholecystectomy is not a satisfactory procedure except in the hands of the most adept operators. The author feels that the personal equation figures largely in gall-bladder operations, and admits he

is temperamentally conservative; and since he gets fair results from drainage intervention, is somewhat averse to the use of the more radical procedure.

By the aid of the *x* rays Cole[48] has made a definite diagnosis of pure cholesterin gall-stones in 30 cases: 16 of these cases were operated, and in 12 the diagnosis was found to be correct. Two of the failures would have been avoided had the entire abdomen being radiographed, as the gall-stones evidently were obscured by the presence of food or fæcal matter. The presence of bile in the gall-bladder causes a deeper shadow than that due to the concrement. By *x* raying stones outside the body, it was found that the presence of a large amount of cholesterin causes the concrement to resemble an air-bubble in the bile. If a number of these stones are crowded together, ring-like shadows appear. These bodies have been hitherto recognized because of the shadow cast by the lime content when sufficiently abundant. We now have, in addition, the 'negative shadows' made by pure cholesterin calculi.

According to Lothrop[49] *acute typhoid cholecystitis* is very rare. A statistical study of thousands of cases gives an incidence of a little over 1 per cent (autopsy cases).

In a series of 200 cases of typhoid cholecystitis, 10 per cent of the gall-bladders contained stones. In another series of 154 cases, perforation occurred in 25 per cent; the mortality in these perforation cases amounted to from 22 to 54 per cent.

C. H. Mayo[50] reports the occurrence of 107 cases of *papilloma of the gall-bladder* in 2538 cholecystectomies at the Mayo clinic during a period of eight years. This condition is not a primary one, but is a complication of ordinary cholecystitis (papillomatous catarrhal cholecystitis). It is due, apparently, to the penetrative action of certain micro-organisms, such as cause infectious cholecystitis, producing, as in other localities under the same conditions, a proliferation instead of a defect. The condition never disappears under incision and drainage.

Davis[51] has made a study of 260 cases of *acute appendicitis* at the Massachusetts General Hospital, in 244 of which the appendix was removed. In 7 of the 15 deaths there was severe general peritonitis before operation. The author admits that careful analysis of the material brought out nothing new. The main cause of death is delay in diagnosis and delay in operation. The family physician and the layman need to have reiterated to them the ill effect of giving a purge during the acute attack.

Eliot, Jr., and Jameson[52] report a series of 5 personal cases of *mesenteric thrombosis*, with 3 recoveries, making the total of reported successful operations for this condition 24. One of the saved patients was a man of 22, another a vigorous man of 38. Their fatal case was a man of 60, who was operated on fifty hours after invasion, death being due to a perforation, the anastomosis having held. The fourth case was in a woman of 57, with intervention eighteen hours after invasion. The operation was the same in all cases, resection and end-to-end anastomosis.

McMahon[53] writes that it has been alleged (Mumford) that about 200 cases of *obturator hernia* have been placed on record, the majority having been found in elderly women, 79 per cent in women over 60. He asserts that the difficulties in diagnosis are so great that it would always be best to

perform a median abdominal laparotomy, though external exploration may be very useful for the reduction of the hernia and for suturing the breech. The mortality in the past has been extremely high—from 50 to 75 per cent, and more recent writers have recommended laparotomy in preference to the direct attack from without. The author believes that by employing laparotomy for all forms of ileus the mortality from obturator hernia will be diminished.

Moots[54] reports a personal case of *inguinal renal hernia*, and finds notes of three others, one of which was found at autopsy. In his own case, the diagnosis was not made until the operation was under way. No other content of the sac is mentioned. The hernial wound was closed, and nephrectomy performed in the usual manner. The kidney was cystic. There are no combined statistics of unusual hernial contents, but 366 cases of hernia of the female pelvic organs were compiled by Andrews in 1905. The author gives neither references nor details.

Up to 1906 but 23 cases of *carcinoma of the small intestine* had been placed on record, but in 1913 Venot and Parcelier increased the total to 50. To this number Lahey[55] adds 2 cases of his own. The first, in a male, was a small adenocarcinoma of the jejunum, annular in form, seated eighteen inches from Treitz's ligament. The operation was enterectomy, with end-to-end anastomosis; most of the adjacent lymph nodes were removed. The other, in a female, was also an adenocarcinoma, small and discrete, in the ileum six feet above the valve. The operation was enterectomy, with end-to-end anastomosis; there were no enlarged glands in the mesentery. In both cases the primary results were excellent, but the woman died of recurrence in five months. The man was healthy and working fourteen months after operation.

Peterson[56] writes of the danger of delay in the diagnosis and treatment of *intussusception* in infancy. Of his own 19 laparotomies for this condition in nurslings, in 13 it was possible to reduce the condition manually, and 9 of the children recovered, the others dying within ten hours after operation. In 6 other cases, where reposition was no longer in question on account of the evolution of the condition, resection or enterostomy was unavailingly used in all but 1 case, in which recovery followed resection. Early diagnosis and prompt intervention will minimize the need for cutting operations.

Bogart,[57] in writing of the surgical significance of *intestinal angioneurotic œdema*, speaks of many cases of what appeared to be acute intestinal obstruction in a number of middle-aged men. The symptoms, which set in acutely, comprised abdominal pain, nausea, vomiting, meteorism, and obstipation. The patients were treated at home by the family practitioner for acute indigestion for a period of about forty-eight hours, when unmistakable symptoms of ileus caused them to be transferred to the surgeon. Nevertheless, in just such cases spontaneous recovery has occurred. In one typical case of apparently acute ileus, operation revealed a swollen and œdematous jejunum. The wound was closed; the symptoms persisted for a time, but at last subsided spontaneously; for a time several areas of œdema appeared on the surface, and one of these had not subsided at the end of twenty-seven days. Although angioneurotic œdema can localize in the intestine, no case of ileus from this cause has ever been reported.

Deaver and Ross,[58] in the German Hospital, Philadelphia, give the

mortality statistics in 276 cases of *acute intestinal obstruction.* This included 156 cases of strangulated hernia, with a mortality of 29 per cent, and 81 cases of post-operative adhesions, with a mortality of 49 per cent. The mortality of the entire series was 42 per cent. For umbilical and ventral hernia the mortality was 42 per cent. These appalling figures are mainly due to slow diagnosis and delayed intervention. With prompt diagnosis and operation the mortality should be but a fraction of this, so that the blame for loss of life must fall upon the family physician rather than upon the hospital surgeon.

McGlannan[59] presents a study of 276 operative cases of intestinal obstruction, with a mortality of 45·7 per cent, the mortality being highest in cases of obstruction of the jejunum and lowest in the cases of colon obstruction. Toxæmia is responsible for 75 per cent of the mortality, for this is extremely hard to combat after it has developed, although it can be forestalled by early diagnosis and treatment. There were 20 deaths in 63 cases of post-operative ileus, and 20 deaths in 29 gangrenous cases of all forms. Enterostomies were performed in 92 patients, with or without other intervention, and of this number 54 died, operation failing to rescue the patient.

Murphy and Brooks[60] have made an experimental study of intestinal obstruction, as a result of which they conclude that enough toxin may be absorbed to cause a disease-picture and death; that these toxins are bacteriogenic, and may occur anywhere in the digestive tract, even in the gall-bladder; that they may reach the circulation through the thoracic duct; that death is not necessarily due to peritoneal or general infection; that as the toxin cannot traverse an intact mucosa, the factors which make absorption possible are the efficient causes, one such factor being the circulatory disturbance caused by ligation, etc.; and that the toxic principle when injected into the veins causes symptoms like those of ptomaines. The chief surgical lesson is that all intestines so damaged as to permit of absorption should be resected rather than drained.

According to Crile,[61] *intestinal stasis,* whatever its cause and mechanism, is itself a factor in the causation of well-known diseases, cardiovascular disease, exophthalmic goitre, diabetes, etc. Indol and skatol, the principal products of auto-intoxication, are adequate stimuli of the kinetic system, so that lesions are caused in the brain, thyroid, liver, and adrenals, these lesions producing modifications of these structures, and resultant functional disturbance or organic disease.

SURGERY OF THE GENITO-URINARY SYSTEM.

Schmidt,[62] in presenting the notes of 35 cases of *nephrectomy during pregnancy,* including one personal, states that the operation has been performed in all months of pregnancy save the first, seventh, and ninth, in one instance being almost coincident with labour. In this series only 2 mothers were lost, and in those who survived, the remaining kidney in no instance failed to compensate for the loss of its fellow. Normal labour followed in 21 cases; in 7 other cases the pregnancies were interrupted in some manner, but it cannot be proved that the operation was solely at fault; in only 4 cases could it be demonstrated that operation affected the child unfavourably.

Brewer[63] reports experiments on animals and clinical cases of *hæmatogenous infections of the kidney*, all of which show that in a bacteriæmia of low virulence, the organisms may escape through the kidneys without causing mischief. If, however, the virulence is higher, or if the kidneys are already damaged, we may not only see fresh lesions develop in these organs, but an overwhelming toxæmia may appear. If one kidney is a vulnerable spot, a surgical lesion may result. Conditions which tend to make one kidney vulnerable are trauma, nephroptosis, calculi, and hydronephrosis. Theoretically these hæmatogenous surgical affections should result from the ordinary predisposing causes of suppuration and sepsis; but in the clinic bacteriological tests may be negative. In contrast to ascending nephritis, descending nephritis is very easily produced experimentally.

The end results of 70 cases of *renal tuberculosis treated by nephrectomy* are reviewed by Crabtree.[64] Prognosis after operation upon young individuals with early lesions of the kidney is less favourable than is the case with older subjects with more extensive lesions, suggesting acquired immunity. The prognosis is worse in the male, who is also much more frequently attacked. The immediate operative mortality, 3·8 per cent, is due to pneumonia, shock, and accident. The late mortality of the author's series was 20 per cent, about one-half of the deaths occurring within the first two years, and the remainder within five years, the lesion being unilateral. The percentage of cures is about 60. In from 55 to 70 per cent of unilateral nephrectomies there was no active tuberculosis five years later. In about 35 per cent of all cases the urine does not become normal, and symptoms persist. In 9 of the 70 cases nephrectomy was performed in vain, as no improvement resulted.

By a research into the literature, and by circular canvassing, Gardner[65] has compiled the enormous number of 1702 operative cases of *bladder tumours*; 1160 of these, however, had already been compiled in 1913 by Watson, and of the remainder, Beer furnishes 50 and the Mayo clinic 114. The author's special service is a compilation of 369 additional cases, in which carcinomata and papillomata predominate, the number of other growths being negligible. In the total series the number of cancers was 661, in 224 of which resection was performed, with an operative mortality of 18·7 per cent; 146 patients were traced, of whom 22 per cent were found to be free from recurrence over three years after operation. In 442 cases excision was performed, with an operative mortality of 21 per cent; 201 survivors were traced, 3·5 per cent being found free from recurrence three years later. Wide resection (Mayo's transperitoneal, Squier's subtotal cystectomy) gives the best outlook for cancer. Beer's method is the only one for papilloma, and may in time supercede resection for recurrent cancer. At present there is no diagnostic criterion by which to distinguish the two forms of growth.

Arteriosclerosis with relation to prostatic operations is discussed by Townsend and Valentine,[66] who offer their paper as a contribution to the study of blood-pressure in surgery. Clinical arteriosclerosis is no contra-indication to prostatectomy, and with good heart action increased arterial tension is negligible, since this will fall after operation. When cardio-vascular and cardiorenal lesions offer contra-indications to a one-stage opera-

tion, a two-stage intervention may be carried to a successful termination. Pre-operative and post-operative periods should be prolonged, the operation itself being rapid.

Gessner[67] reports some experimental work on the *circulation of the testicle*. The experiments on dogs were performed to determine methods of operating for cryptorchidism, varicocele, etc., and consisted in dividing or ligating various portions of the cord while others were left intact. The author's findings led him to believe that the whole cord should not be severed, although the vas deferens, the artery of the vas, and its veins, should all be divided individually. If man's testicle were but a single organ, the ordinary technique of the operation for varicocele, and Bevan's method for undescended testicle, would have to be abandoned. Apparently the author leaves intact the spermatic artery and veins, the nerves, and the lymphatics, as essential to the maintenance of the circulation of the testes.

Judd[68] finds 93 cases of *cancer of the prostate* in his series of 878 prostatectomies, and adds to this 84 more cases not subjected to operation. Of these cancers, 75 developed in hypertrophied prostates. Of the total number, data obtained from 82 cases showed that 24 died within six months, and 5 others died after an unknown interval. One patient is living and well nine years after operation, 2 after four years, 3 after three years; to these should be added 8 known to have survived three years, but since lost trace of. Thus at least 14 passed the three-year limit, 16 others are or were living two years after operation, and 20 one year after. Many of these patients are known to be in good health. An actual list of recurrences is not given by title, but the number who have had or may have had recurrence would appear to be 34.

A discussion by Tenney and Chase[69] of the *mortality after prostatectomy* is based on a study of 229 fatal results. In one collection of 160 cases, uræmia caused death in 30 per cent, hæmorrhage and shock in 22 per cent, embolism in 12 per cent, sepsis in 11 per cent, pulmonary complication in 10 per cent, and cardiac disturbance in 9 per cent. Uræmic death may occur in the apparent absence of all factors which precipitate it. Hæmorrhage, shock, and sepsis may often be due to the very means taken to prevent shock, namely, rapidity in operating, which leads to rough work. The danger from embolism and from pulmonary complication is inherent in prostatectomy. With carefully selected material, the mortality has been less than 2 per cent, while 20 per cent is not an excessive hospital mortality.

SURGERY OF THE DUCTLESS GLANDS.

Dowd[70] tabulates 13 cases of *cavernous angioma of the spleen*, including 1 of his own. In 6 of these cases splenectomy was performed, with 2 recoveries and 3 deaths, there being no information regarding the sixth case. Of the 7 unoperated cases, all died from the disease, which appears to possess at times a sarcomatous component. The author lost his own case, which was in a woman, age 37, who died from hæmorrhage in an angioma of the liver two and a half months after splenectomy. In this case no sarcomatous tissue was found.

Mayo, W. J.,[71] in writing on the mortality of *splenectomy*, says that the operative risk is encountered almost entirely in cases with large adherent spleens, associated with a high grade of anæmia and œdema of the limbs, changes in the myocardium and kidneys, ascites, jaundice, high fever, etc., several of these factors being usually co-existent. Of 58 cases of splenectomy for splenomegaly, the great majority were of this severe type, yet there were but 5 operative deaths, and 2 of these might have been prevented.

Wilson[72] makes use of the material afforded by the Mayo clinic in a study of spleens removed for certain abnormal conditions of the blood. The material consisted of 31 spleens removed between Dec. 3, 1912, and June 9, 1915, and of 26 others reported between November, 1905, and November, 1912. The clinical diagnosis, as based chiefly on blood-counts, fell under nine different captions, showing that there is more or less confusion in nomenclature as yet. Of the 31 cases, 15 were examples of splenic anæmia, and 7 of acquired pernicious anæmia, leaving 9 cases with seven different diagnoses. In 2 cases there was hæmolytic jaundice, in 1 hæmolytic anæmia, and in 1 lues; these four cases arranged themselves pathologically with splenic anæmia. There was 1 case of lymphosarcoma. In 3 cases the only cause or characteristic is given respectively as sepsis, fever, and eosinophilia. This report complements one by Giffin, also of the Mayo clinic.

Giffin[73] reports on splenectomy for splenic anæmia in childhood, basing his conclusions on 68 splenectomies for various conditions performed at the Mayo clinic, only 1 of which, a recent case, was done on a subject in the first decade. This case was a girl two and a half years old, who suffered from secondary anæmia. A good recovery resulted. The splenomegaly here was of an adult type. There has never been a case of the infantile form of splenic anæmia at the clinic, and in the literature the author finds only 4 cases, in all of which splenectomy was performed successfully. Of the adult form of splenic anæmia in childhood, 7 operative results have been reported; but the author questions the correctness of the diagnosis in some of these cases.

Giffin[74] publishes also the results of an analysis of 58 splenectomies performed in the Mayo clinic since 1904. Of these, 27 were for splenic anæmia, or, as it appeared, primary splenomegaly; there were 3 operative deaths, and ten years later 8 had died in all. Operations for pernicious anæmia have only been recently performed. These number 7, with 1 operative death, and a second death in two months; these cases have been distinctly benefited. Numerous operative opportunities were refused by the staff. Early in the series were 3 cases of Gaucher's disease, non-familial. There were 5 cases described as secondary to infection or sepsis, 3 associated with lymphoma or lymphosarcoma, and 2 with syphilis; in addition to these there were 11 cases in which eight diagnoses were made.

Elliott and Kanavel[75] tabulate 48 cases of splenectomy for hæmolytic icterus, comprising 16 acquired cases, 23 hereditary or familial, and 9 unclassified. Clinically there were no pronounced distinctions. Of the 48, only 2 ended fatally, one from primary and one from secondary causes. In 46 cases the jaundice was nominally cured, yet many of the operations were too recently performed for percentages and end-results to be established. Even

in cases of prolonged recovery, extending over decades, the blood-corpuscles may still retain their fragility—which as far as is known has always increased before operation, but the blood picture was always immediately and favourably influenced by operation. In the vast majority of cases the jaundice disappeared within two weeks, and often very promptly after the surgical intervention.

Porter[76] advocates the use of *boiling water injections into the thyroid gland for hyperthyroidism*, believing that this method of treatment can properly replace so-called medical measures in small goitres with moderate symptoms of hyperthyroidism, and even in cases in which the symptoms are severe, if the hyperplasia is both slight and circumscribed. Boiling water injections are especially valuable after lobectomy when some hyperplasia must persist. In large goitres accompanied by severe symptoms this treatment should also render inoperable cases operable. It is contra-indicated in the simple non-toxic goitre. Over 100 cases, with 1 fatality, have now been treated by this method by the author himself and a number of his friends. The fatality was the result of psychic shock, or almost maniacal excitement, ending in exhaustion, but could not be attributed to the single injection which had been made.

MISCELLANEOUS.

A study of 75 cases of *betel-chewer's cancer* of the buccal mucosa in the Philippines forms the basis for a study of buyo cheek cancer by Davis.[77] In 50 of these cases the destructive process extended through the cheek, appearing as an external ulceration or typical cheek cancer. These growths belong to the typical focal epitheliomata which have a fixed cause in specific forms of irritation, as *x*-ray cancers for example. The buyo cheek cancer is not necessarily due to perforation, for it may spread from the inner aspect of the mouth to the lips and then involve the cutaneous surface of the cheek. Severe regional lymph-node metastases occur, and only the most radical operation can arrest the disease. There is a high mortality from post-operative pneumonia. The true irritant, as has long been known, is the lime which is chewed with the leaves. These growths would seem to be wholly preventable.

Pyorrhœa dentalis and alveolaris, according to Bass and Johns,[78] is practically a universal disease, which leads to loss of the teeth by a long suppurating process. All people have it sooner or later. The specific cause is *Entamœba buccalis*, or possibly other species which infect and destroy the peridental membrane. The pyorrhœa results largely from secondary infection. The demonstrable amœba can be destroyed by hypodermics of emetine in half-grain doses administered for from three to six consecutive days. On account of the dangers of relapse, this treatment must be repeated from time to time until there is no longer any sign of the disease. Emetine may also be injected directly into the worst lesions.

While in ordinary practice an acute tonsil is seldom removed, Archibald[79] reports 7 cases in which *complete bilateral tonsillectomy* caused rapid improvement in choreic cases. Ordinary chorea is known to be akin to rheumatic affections, and, like other conditions comprised under the latter head, may

have originated in an angina. Clinically, chorea and diseased tonsils often coexist. Adenoids, if present, should be removed with the tonsils. In the seven cases noted in this paper, an indication to remove the tonsils was as a rule present *per se*, by reason of their great size and pathologic condition; their removal for the relief of the chorea seemed to be a secondary consideration.

To Torek[80] belongs credit for the sole case of successful *resection of the thoracic œsophagus for cancer*, the patient being alive and in good health twenty and a half months after operation. In all preceding cases, death has occurred from either primary or secondary operative mortality. Torek first performed a permanent gastrostomy, and then attacked the œsophagus through the pleura. The incision followed the entire length of the seventh intercostal space, and was prolonged above, vertically, to the third space. The fourth to seventh ribs were divided between the tubercle and angle, while a rib spreader was inserted between the seventh and eighth ribs. Intratracheal anæsthesia was then used, and the pleura incised through the first incision in the seventh interspace. The lung collapsed slightly, and lung retractors were not used. After being drawn out and isolated, the œsophagus was double-tied and divided. The upper segment with the cancer was drawn out through a special incision in the neck, resected, and the stump sutured to the wound, the chest having already been closed.

Meyer[81] reports 5 unsuccessful cases of resection of the œsophagus for carcinoma, believing that unsuccessful no less than successful cases should always be made public. The first two cases were found upon exposure to be inoperable, while the third patient died on the table before resection could be performed. The fourth case ended fatally after resection had been done, while in the fifth case death ensued in the interval between the first and second stages. Meyer now has a series of 8 of these cases, and in but 2 of these was resection actually indicated. He now feels in a position to select cases which hold out a promise of recovery. Two collateral procedures are necessary in every resection: (1) The proximate stump of the œsophagus must be withdrawn from the mediastinum, and transposed under the skin of the thorax in front and downwards; (2) The pleural cavity must be drained immediately after operation.

Warthin[82] bases a study of *malignant neoplasms in the young* on 2000 cases examined microscopically in the pathological laboratory of the University of Michigan for the period from 1895 to 1913. By 'the young' the author implies any age up to 30. The cases which occurred in the first three decades numbered 195, or nearly 10 per cent of the entire number. The proportion of males and females was about five to four. Sarcoma exceeded cancer in about the same ratio. Apart from sarcoma and cancer, the only neoplasm occurring to any extent was malignant teratoma—in nearly 10 per cent of the cases, about half of these appearing in the testes. The location of cancer and sarcoma was so varied that generalizations were not possible, excepting that for the most part they followed the locations of these growths in the adult—that is, the breast, uterus, and lip for cancer, the long bones and jaw for sarcoma.

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[72] WILSON, *Ibid.*, 158.
[73] GIFFIN, *Ibid.*, 679.
[74] GIFFIN, *Ibid.*, 166.
[75] ELLIOTT and KANAVEL, *Surg. Gyn. and Obst.*, 1915, xxi, 21.
[76] PORTER, *Ibid.*, xx, 1.
[77] DAVIS, *Jour. Amer. Med. Assoc.*, 1915, lxiv, 711.
[78] BASS and JOHNS, *Ibid.*, 553.
[79] ARCHIBALD, *Collected Papers Mayo Clinic*, 1914, p. 7.
[80] TOREK, *Annals of Surg.*, 1915, lxi, 385.
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[82] WARTHIN, *Arch. Int. Med.*, 1915, xv, 444.

SHRAPNEL WOUND OF THE POSTERIOR WALL OF THE PERICARDIUM: REMOVAL OF THE MISSILE.

By Hon. Major R. SCOT SKIRVING, A.A.M.C., Sydney, N.S.W.

The management of injuries to the heart and pericardium is now set forth in all treatises on surgery, but the actual number of recorded cases is not in the aggregate very great. I hope, therefore, I am justified in publishing the following example, which shows some of the difficulties of *x*-ray diagnosis, as well as the anatomical and physiological risks in operative interference with this part of the body.

The patient, a strong, wholesome-looking young soldier, age 22, was wounded somewhere in France, on Oct. 11, 1915. He was hit under the left axilla about the posterior axillary line. The missile travelled obliquely through his lung, and there was no wound of exit. He suffered much from shock, remained practically unconscious for three days, and spat blood profusely for over a week. During that period I gather that the physical signs of pericarditis were present. He was sent to England on Oct. 27, and after periods of rest in several hospitals, was ordered back to his regiment. It was then seen that he was quite unfit for duty, because of his shortness of breath on exertion and the presence of deep-seated pain in his chest. Under these circumstances he came under my care on Feb. 7, 1916. He had the above-mentioned complaints, and stated that if he walked briskly or attempted to go upstairs " he was brought up all standing."

On examination, the scar of an irregular lacerated wound in the left axilla was seen. It had healed soundly, and need not detain us further. His general health was excellent, and he had no physical abnormality other than those connected with his heart and breathing. The lungs presented no pathological change demonstrable by physical examination, except that, owing to his former occupation as a coal-miner, the *x*-ray shadows in the pulmonary area were considered darker than usual. As to his heart, his pulse was small and rather soft, always fast, usually over 100 per minute, and occasionally a beat was missed. The heart dullness was not outside the normal limits, nor was the apex beat. The first sound in the mitral area was replaced by a soft blowing systolic murmur, not specially conducted into the axilla. I did not like to make him exert himself actively for purposes of comparison; but, on the whole, the murmur was probably loudest when the patient was at rest. There was very marked reduplication of the second sound, especially in the pulmonary area. No pericardial friction was now to be heard.

The *x*-ray examination showed a foreign body situated apparently at or about the upper reflexion of the pericardium, to the left of the middle line, posteriorly. This object, on the screen, could be seen to move—probably

with the heart's movements, though some of those who witnessed this strange sight thought the excursions were slower than those of the heart itself. Possibly the movements were of both cardiac and pulmonary origin, for it seemed to move vertically with the respiratory and laterally with the cardiac excursions ; also it rotated on its vertical axis, as if one part was more fixed than the other. In these examinations I had the assistance of the special skill of Mr. Reid, of St. Thomas's Hospital, as well as that of Mr. Henry and Mr. Pooley, of Queen Alexandra's Military Hospital, also expert and experienced radiographers—to all of whom my thanks are due. Any operation on this case would have been out of the question without the knowledge gained from specially capable radiographers using very fine instruments. The photographs illustrating this paper are also their work.

The final deduction from the physical and radiographic examinations was that a piece of metal, probably a bit of shrapnel casing, had gone obliquely through the left lung, perforated the pericardium from behind at its upper reflection, and was now embedded partly within the sac, partly without, and lying upon or between the pulmonary veins. The risks of any effort to remove it were explained to the patient, also the chance of failure, and the possibility that even its successful removal might fail to remove his breathlessness and pain. He very pluckily decided in favour of the operation, on the ground that neither delay nor rest had done him any good, and that he was incapable of earning a living, or indeed of any sustained exertion.

I accordingly operated on March 21, 1916, Col. Pilcher and Col. James, with Lieut. Lock, assisting me. Major Starling was present, and gave me valuable advice regarding the manipulation of the living heart, a matter with which his researches in cardiac physiology in animals had made him familiar. There are various ways of fully exposing the pericardium, but the method used in this case was found thoroughly satisfactory. It gave ample access. There are a few practical details, not dwelt upon in text-books, that I think worth mentioning.

Operation.—An incision was made from the centre of the sternum at the level of the 6th costal cartilage, following the line of that structure outwards and downwards to its union with its rib ; this incision should be bellied downwards to demonstrate the lateral bridge joining the 6th to the 7th cartilage. The soft parts were now suitably retracted, and the cartilage was laid bare. The pleura lies closely below the outer part, so the separation of the cartilage should begin at its inner end, which lies over the 'triangle of safety,'* where the pleura does not reach.

The perichondrium is difficult to separate on the external aspect of the cartilage, but happily it is easier to do so on the internal, where the risk of wounding the pleura is a very real one. I cut the cartilage at its inner end, and at its lateral union with the 7th cartilage, using the point of the scalpel, carefully avoiding any sudden plunge of the knife through the cheese-like

* 'The triangle of safety' is a term which has been applied to that little area of pericardium which is normally not covered by the pleura. Internally, its base lies between the fifth and seventh chondrosternal joints, and the root of the xiphoid cartilage, while the apex of the space is about two and a half inches out in the fifth interspace.

cartilage. After removal of the whole of the 6th cartilage, the fan-like triangularis sterni muscle came into view, and was divided. The internal

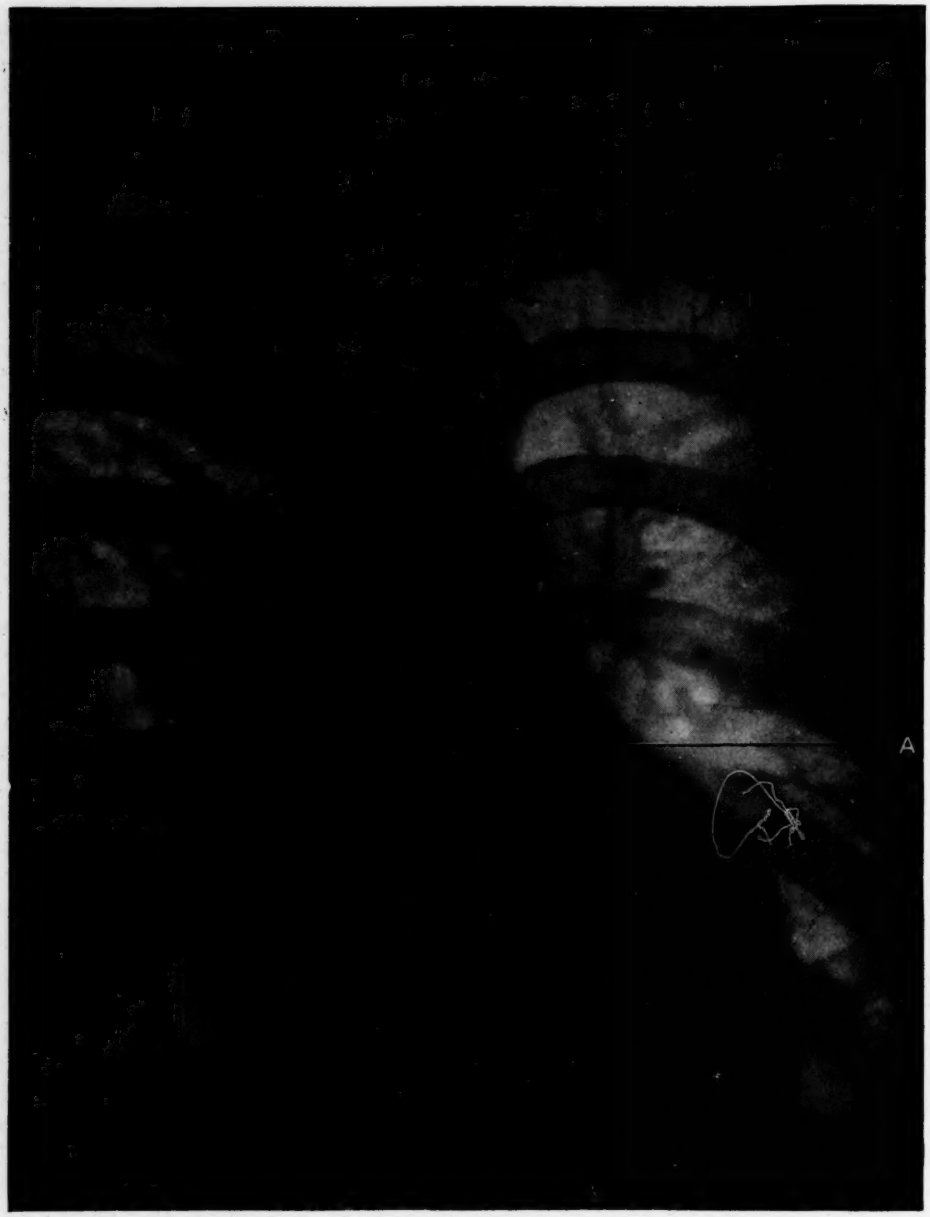

FIG. 41.—Anteroposterior view of the chest, in which the foreign body, lying with its sharp edge end on, looks rather like a rifle bullet. All the other marks seen are merely metal objects placed on the skin as landmarks.

mammary vessels were then dealt with. I cut the artery, and tied both ends; it was very small, and gave no trouble.

The pleura was now clearly recognized, and the presenting part pushed upwards and outwards with gauze. A vertical incision rather to the left of

FIG. 42.—Lateral view of the chest; the lozenge-shaped appearance of the missile is plainly visible. The other objects on the surface are only landmarks.

the mid-sternum was then made to the level of the second rib, and a little later the skin incisions were completed by a third cut from the upper end

of the last incision, outwards and nearly horizontal, about 2½ or 3 inches in length. This marked out an irregularly shaped box-lid flap.

The periosteal and other tissues covering the sternum were pushed outwards with Faraboeuf's rugine, carrying this clearance beyond the insets of the cartilages of the 5th, 4th, and 3rd ribs, which were carefully cut through vertically. (It might be quite a neat plan to divide them in such a V-shaped way that on replacement a piece of the outer end would dovetail into the corresponding aperture in the inner fixed portion.) I now raised the whole flap of cartilage, muscle, and skin, at the same time gently stripping the underlying pleura off its inner surface as far back as was necessary. The flap so raised could be held well up, and I did not find it necessary to crack the cartilages at their outer extremities.

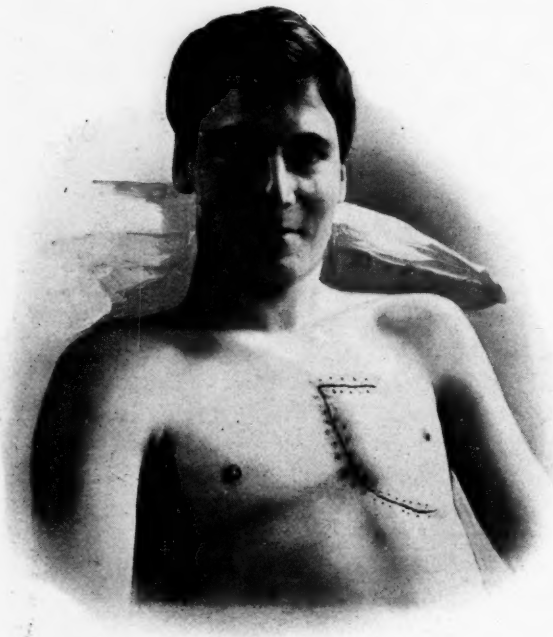

FIG. 43.—Photograph of chest, showing lines of incision.

One could now see the dark, obliquely placed edge of the lung, like a shadow, about 1½ inches external to the left side of the sternum, rising and falling under the thin veil of the pleura, which still covered the upper part of the pericardium. Colonel Pilcher wisely reminded me at this stage that the pleura was here still *in situ*, hiding its actual reflection under cover of the sternum—a most timely warning, for one is apt to forget that the lung itself does not overlap the pericardium to the extent that its investing pleura does. It is indeed very easy to wound the pleura in this operation, although doing so need not make one unduly sad. However, I managed to sweep it safely from below upwards and outwards. It came easily from under the sternum, and was pushed, uninjured, well out of the way. The pericardium was now fully exposed. An opening was made in it, and it was seen that the cavity was largely occupied by soft, sticky, blood-stained adhesions. This, in a way, was hopeful, as it suggested that the metal was probably within the sac. The pericardium was now slit nearly throughout its whole extent, from above downwards. The adhesions, which were many, were fortunately soft, and I swept them all asunder with my finger without difficulty or any bleeding worth mentioning.

On passing my hand behind the heart up to the base, posteriorly, I felt a hard substance embedded in soft cicatricial tissue. Professor Starling advised me now to give the heart little spells of repose, by withdrawing

my fingers from within the sac. This is really an important point, for although the heart will stand quite a lot of handling, including turning it out of the pericardium, as long as one avoids actually kinking its base or keeping the hands touching it for too long at a time, yet it needs a rest from mechanical stimulation at short intervals. The value of these intermissions was specially noticed by the anæsthetist at this period of the operation. I soon was made happy by scraping the hard mass with my finger and feeling a sharp point of metal. With a curved blunt dissector I began to free it gently from the embrace of the posterior wall of the pericardium. About two-thirds of the whole mass seemed to lie without that structure, and rested, as I thought, on or between the pulmonary veins, not a comfortable neighbourhood. It was really quite thrilling to see the heart heaving and writhing before one's eyes like a squirming hairless reptile, and this effect was increased by the thought that perhaps when the metal was actually freed, a fatal gush of blood might follow its delivery. However, all went well, and the missile was delivered without any considerable bleeding.

I knew of no means worth trying to prevent the pericardial adhesions re-forming, and can only hope that the removal of the exciting cause may have a quieting effect on their growth. The pericardium was sewn up with catgut—using Halsted's sutures, and taking great care to evert the lips of the incision so as to leave only a clear serous surface within. The displaced pleura was then encouraged to take up its normal position. The flap containing skin, muscle, and cartilage was allowed to fall back into its proper place; the cartilages were anchored with stout catgut stitches, and the periosteal tissues over-sewn at the points of section. The edges of the incisions were closed in the usual way, without drainage. It is perhaps worth while saying that the dressing of gauze and wool pads was kept in place with strips of adhesive plaster; and, in order to keep the pectoral muscles quiet, the left arm was laid alongside the body and fastened there by a broad flannel binder embracing it and the chest, leaving the right arm free. The patient was nursed throughout in the semi-recumbent position. These points are of importance, because the union of cut cartilage is unsatisfactory, and by immobilizing the arm, the fixation of the divided ends by suture and oversewing was given a better chance to result in a fairly firm union.

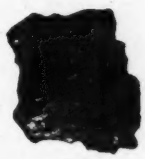

FIG. 44.—Photograph of missile. (*Actual size.*)

Anæsthesia.—In cases like this, in which the pleura is likely to be opened, the choice of an anæsthetic and the method of its administration are important questions. In this case I had the kind help of Mr. Rood, of University College Hospital, who gave ether and oxygen in varying proportions through a tracheal tube connected with the usual apparatus for tracheal insufflation (Meltzer's method). This was employed mainly in view of any possible accidental opening of the pleura. If I had failed to get the metal out through the pericardial route, I intended to open the pleura and seek for it in the anterior cul-de-sac of that cavity. This would have meant some collapse of the lung. My reading and experience of pleural operations (chiefly in hydatid disease) leads me to believe that this event is

not by any means so serious a matter as was formerly supposed. To begin with, free collapse of the lung needs more than the mere opening of the pleura, for the stickiness of the layers keeps them together, and so maintains the condition necessary to prevent any extensive collapse. Moreover, pleural adhesions in adults are not uncommon, and also hinder general collapse of the lung. Again, granting that partial collapse does take place, it is not an unmixed evil in cases like the present, for it diminishes the excursions of the heart's movements, and makes more room in the chest for manipulations of or about the heart. However, admitting all this, one does not willingly open the pleura in this operation; and if by accident one does do so, it makes one's mind easier to have the intratracheal method of giving anæsthesia in action, to keep the lungs inflated and maintain normal pulmonary ventilation. Moreover, by keeping the lungs distended and the pleura in its normal state, one is less likely to wound it accidentally when turning back the big flap or when sweeping the surface of the pericardium of its overlying reflexion of pleura, which is very thin and fragile.

As regards tracheal anæsthesia, therefore, it is better, in my judgement, to try and obtain the added comfort (I refer to the operator, not the patient) of this apparatus, and a competent man to use it. If, however, this should be a counsel of perfection, there seems no reason why one should hang back from doing the operation without this aid, if the necessities of the case demand it.

After-history.—Happily, this has been quite uneventful. There was hardly any post-operative shock, and no temperature, but the former quick pulse persisted, nay, rose to 126 per minute, and lasted for several days. By the tenth morning it had fallen to 80, the patient felt perfectly comfortable, and the wound was well healed. I propose keeping him in bed for forty-two days. I think some sort of breastplate of aluminium or felt should be applied to act as a shield to his weakened chest wall.

I am under no delusions about the future of this patient. I am not so sanguine as to think that because I had the luck to remove this bit of metal all his disabilities will disappear. I think that his chest pain may be relieved. I believe there will be no increase in the pericardial adhesions; but I certainly expect some permanent 'hobbling' of the heart as a result of their re-formation and firm establishment. I wish I could have tried, with faith, some means of preventing the re-growth of these adhesions in this rather sacred region.

Lastly, although I do not think it likely, it is possible to imagine that one or other of the great vessels against which the foreign body lay pressed may have had the integrity of its wall damaged, and some sort of aneurysmal change may yet develop. [*Ref. No.* 128.]

GUNSHOT WOUND OF PERICARDIUM AND HEART: PNEUMOHÆMOPERICARDITIS: OPERATION: RECOVERY.

By Major LITLER JONES, R.A.M.C

Pipe Major T., age 38, was wounded on Oct. 1, 1915, by high-explosive shell, and admitted to hospital on Oct. 3 with two shell wounds of the chest wall and one of the left forearm. His pulse-rate was 77, respiration-rate 32. Of the two wounds of the left chest wall, one was in the fourth intercostal space, three inches internal to the nipple line, the other in the seventh space, in the nipple line. The wounds were—as is usual—infected. The fragments of shell had penetrated the chest wall. The

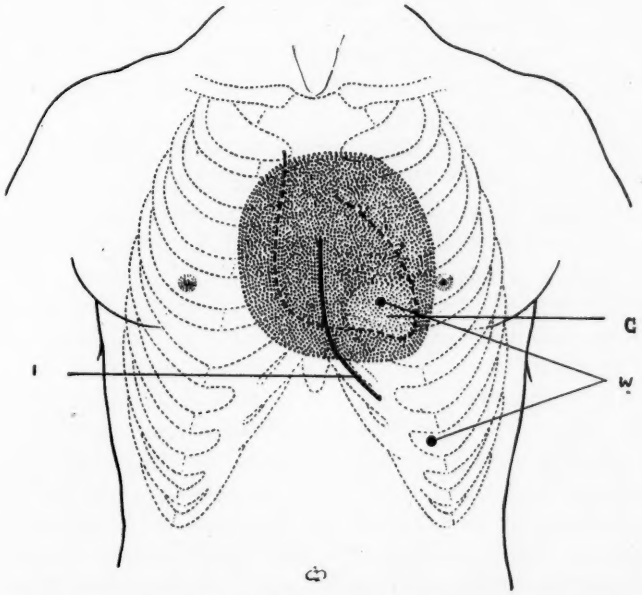

Fig. 45.—Drawing made from *x*-ray photograph of chest, showing pericardial effusion due to gunshot wounds. The dotted area represents the *x*-ray shadow of the pericardium. G, Area showing gas; W, The two wounds; I, The incision.

wound in the arm was explored, and a fragment of shell removed. The patient was expectorating blood. The breath sounds were faint and impaired over the left base. The heart sounds were very faint. There was dyspnœa, and great complaint of inability to sleep. Dullness extended across the chest from one base to the other, and both pleural cavities were suspected of harbouring fluid.

Four days later the patient had not slept, or, if at all, only for the briefest

intervals; the cardiac sounds had entirely disappeared, so much so that another stethoscope was asked for on the supposition that the one in use was blocked. The rate and volume of the pulse were much the same, but the patient was dusky, much distressed at the inability to sleep, and complained of a stretching pain at the back of the left chest. He was too ill for an examination of his back. A stimulating expectorant was administered, and the blood-stained expectoration had ceased by the sixth day.

On the eighth day he was more exhausted by loss of sleep. His sclerotics were icteric. His pulse-rate averaged 70, and his temperature was normal. There was no œdema of the chest wall, such as I have twice since seen in hæmopericarditis.

Although the man was very ill, on Capt. Hayward's suggestion he was taken on his bed to the *x*-ray room and screened in the 'sitting-up' position, which he favoured, to confirm the diagnosis of pericarditis and to ascertain the condition of the pleural cavities. It was at once apparent that the extensive dullness was sharply localized, and due to an extensive pericardial effusion. Also it was apparent that there was little, if any, hæmothorax. An *x*-ray plate was taken in this difficult position, and the drawing made from it (*Fig.* 45) illustrates the condition.

The patient being in great distress, it was obvious that either fresh hæmorrhage had taken place or that infection had occurred. An operation to expose the pericardium and heart was decided upon.

Ether anæsthesia was induced. The incision made was that following the border of the seventh costal cartilage and the mid-line of the sternum; portions of the seventh, sixth, and fifth costal cartilages, and half the width of the sternum, were removed, thus giving sufficient room to introduce at least two fingers and a thumb to grasp the heart if the necessity arose—if it were still bleeding or recommenced to bleed—and steady the organ for suture. The pericardium was well exposed, and was incised vertically for two inches. The heart at once plugged the wound. On pushing that organ backwards, a large quantity of foul-smelling gas escaped, followed by froth, and later by stinking fluid which was blood-stained. We estimated the amount of gas that escaped as being as much as would displace 6 ounces of water. The fluid, which had a most foul smell, measured 22 ounces; the pathological report on it was that *Bacillus perfringens* and enterococci were grown, and also a few staphylococci. The fingers were at once introduced into the sac, and adhesions separated between the heart and the floor and wall of the pericardium. The foreign body was not in the pericardium, but had guttered the anterior and upper border of the heart, penetrated the sac wall and pleura, and entered the left lung. There was no recent hæmorrhage. Only the most careful examination of the injured area of the sac wall was made, so as to avoid infecting the pleura if it were fortunately sealed off, as we had reason to believe was the case from the *x*-ray screening. The patient's colour, which had—up to the moment of opening the pericardium—been dusky and dull, at once assumed a healthy aspect, and his pulse became stronger. The fluid and blood from the breaking down of adhesions was mopped out, and a flanged rubber drain introduced through eusol dressings into the pericardial sac. The heart itself was tolerant of manipulations, and remained so

during the subsequent dressings. Part of the wound in the chest wall was sutured together. The patient, much relieved by the operation, was put back to bed.

The pericardial cavity was syringed out with warm eusol, which certainly acts as a great deodorant. Large quantities of lymph formed which coagulated, and this had to be picked out with forceps at every dressing. The eusol caused some pain. Hypertonic saline was tried, but caused great pain, which was always referred to the middle of the back. Saline solution of normal strength was tried also, but this too was complained of. However, iodine solution, one drachm to the pint, suited him at once, and this strength —or two drachms to the pint—was used until the wound had entirely healed, which occurred in seven weeks. One piece of tough coagulated lymph resembled a cast of the posterior part of the pericardial sac. Pushing the heart out of the way caused no sensation or distress, and he was unconscious of the movement.

The *x*-ray plate shows distinctly the much-distended pericardial cavity and its almost circular shape, and also the more transparent area towards the centre of the opacity due to the contained gas, which was not suspected before operation (see *Fig.* 45). The entire absence of heart sounds before operation was a most conspicuous clinical feature. The congestion of both bases suggested some fluid; the right base was more suspected than the left. Owing to the large quantity of gas and fluid in the pericardium, one was apprehensive that when the sac contracted, infected material would remain in the posterior part of the right recess of the pericardium, and that the healing and closing of the wound would add still further to the difficulty. At one time I considered the possibility of draining the pericardium from behind, and if the left lung had been collapsed, I should have had, I think, little difficulty. On a few occasions a catheter was introduced behind the heart, and the fluid sucked out; I was unable to procure a saliva exhauster at the time. The cavity was always filled with lotion at body heat; the heart churned it up with the fragments of lymph; and this was mopped out and repeated until the lotion remained clear.

There is one point in dealing with costal cartilages that is worth bearing in mind: they heal slowly, and are best sectioned as short as is possible, leaving them undisturbed in their perichondrium, and concave. If left protruding from their membrane they heal slowly.

Pericardicentesis, judging by the numerous 'best spots' given by different authors, is unreliable, apart from the usual danger. In this case there was the added risk of sepsis; and had a trocar or aspirating needle been introduced, and the heart not punctured, as it almost certainly would have been, gas or froth would have been withdrawn. Possibly the pleura would have been suspected, as gas in the pericardium is certainly unusual. The pleural cavity never became infected.

During the convalescence of the patient, the base of his left lung gave us some anxiety. His urine at one time only measured twelve ounces in the twenty-four hours, and œdema of the loins was present, but the albuminuria was slight in amount. At this time his pulse became barely perceptible, but never alarmingly frequent.

There have been many discussions as to the position of the heart in pericardial effusions. In this case the heart was anterior, and in close contact with the chest wall, and this in the presence of a large effusion of gas and fluid. In two other recent cases of hæmopericarditis due to gunshot wounds, where expectant treatment proved successful, the heart sounds could only be heard at the base of the heart over the sternum in one, and only very faintly in the other; but I have no evidence to offer as to whether the heart was more anterior than posterior.

The wound has long since firmly healed, and Capt. MacIlwane has kindly examined the patient by the electrocardiograph.

"*Examination of Cardiac Condition*, Jan. 16, 1916.—There was no evidence of any hypertrophy or dilatation being present. No murmurs were heard; none of the cardinal signs of adherent pericardium were observed.

"The systolic blood-pressure was 108 mm. Hg, and the diastolic pressure 85 mm., by auscultatory method.

"The electrocardiogram showed a regular rhythm, with no abnormal mechanism of beat except a slight inversion of the 'T' wave in lead 11.

"It was difficult to map out the left margin of the heart at the apex, as the cardiac dullness was continuous with the dull area in the axillary region.

"An *x*-ray plate taken by Capt. Crymble showed that there was no increase in the size of the heart."

The patient has apparently every chance of regaining robust health, judging by his progress here in France and a report from home. He enjoys short walks, his urine is normal, he has no œdema of the ankles, and in short, as far as it is possible to say, he has regained his former condition.

I would like to thank my colleagues and the nursing staff for their help in this case. The skilful dressing of this patient, which was of frequent occurrence by night as well as by day, probably just made the difference. [*Ref. No.* 114.]

THE PITUITARY FOSSA, AND THE METHODS OF SURGICAL APPROACH THERETO.

By V. ZACHARY COPE, London.

During the past ten years a vivid scientific light has been focussed on the pituitary gland, and our knowledge of its functions in health and deviations in disease has been greatly increased. The physician and neurologist have found that increase or diminution of glandular function leads to recognizable clinical symptoms, whilst general surgeons and rhinologists have been asked to operate for conditions of the gland which lead to these symptoms and are amenable to surgical treatment. Yet, in spite of the excellent work done, no general agreement has yet been attained as to the best route of surgical approach. The present study aims at supplying some facts which may help to determine the best surgical procedure.

ANATOMICAL CONSIDERATIONS.

A pituitary body is present in all vertebrates, but in the lower types the protection afforded by the skeleton is not so specialized as in mammals. In fishes, with a persistent cartilaginous skull-base, a shallow depression for the

Fig. 46.—Skull of tortoise, showing pituitary fossa. (*R.C.S. Museum.*)

gland can be seen. In the lower reptiles (e.g., sphenodon), towards the anterior end of the bony floor of the skull there is a small depression for the pituitary, overhung by a ridge of bone which corresponds to the dorsum sellæ of higher

vertebrates. When we examine such well-developed skulls as those of the higher reptiles (alligator or tortoise), we find a well-protected deep excavation in the body of the sphenoid (*Fig.* 46). Birds have a small and insignificant fossa; but the majority of mammalian skulls show a well-marked depression, built more after the pattern of the higher reptiles.

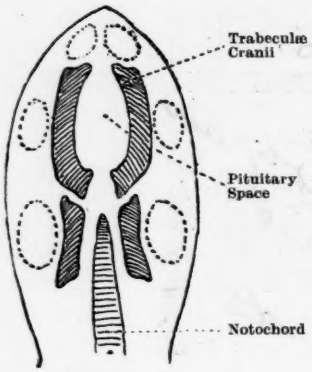

FIG. 47.
Scheme of embryonic skull-base.
(*After Wiedersheim.*)

The pituitary fossa is formed at a nodal point in the base of the skull between the trabeculæ cranii and in front of the notochord and parachordal cartilages (basal plate) (*Fig.* 47). It is situated just behind and above the nasal capsule, and varies in shape and position according to the relation which the facial skeleton bears to the cranium. A study of the higher vertebrates' skulls shows that it is a function of the basi- or postsphenoid to form the pituitary fossa. This can be seen best in the skulls of those animals which have no sphenoidal sinus, such as the sheep or seal, here illustrated (*Figs.* 48, 49). In animals with well-developed sphenoidal sinuses (for example, the pig), or in which the facial skeleton is placed more under the forebrain (as in the chimpanzee), the presphenoid may form a small portion of the anterior wall of the fossa (*Fig.* 50).

In the human embryo the fossa is formed in cartilage at a very early stage. In a reconstruction model which by Professor Frazer's kindness I was able to make of an embryo of 28 mm., a recess with a well-marked posterior wall can be observed at the anterior extremity of the basal plate. This posterior wall, which is the future dorsum sellæ, is made up of cartilage and membrane. At this time there is no anterior wall to the fossa, and the condition is more akin to that found in the lower reptiles. Apparently the anterior boundary of the fossa is elevated by the upgrowth of the facial skeleton, and thus the normal shape of the fossa is completed. Bony nuclei are laid down in the cartilage of the postsphenoid region around the fossa at about the eighth week of fœtal life. The nucleus of the basisphenoid forms the base of the fossa, and the presphenoid bony deposit does not, at first, form one of its boundaries. At birth, the fossa can be seen surmounting the basi- and part of the presphenoid, and the cartilage between the two can be seen stretching from the nasopharynx to the antero-inferior part of the sella. At this time the clinoids and the dorsum sellæ are not ossified fully.

The craniopharyngeal canal, which represents the route along which the pharyngeal portion of the pituitary gland enters the skull to meet its nervous counterpart, is generally closed long before birth, but may persist longer. This canal traverses the anterior part of the postsphenoid, and does not lie between the pre- and postsphenoid, as is generally stated. A comparative study of mammalian skulls made me regard the current statement as incorrect, and actual examination of fœtal skulls soon showed the remnants of the canal in the basisphenoid. This can be seen in *Fig.* 51. Though the correct position of the craniopharyngeal canal is not correctly given in most text-books, its

relation to the postsphenoid is accurately figured in some Continental communications.[1] Erdheim has related an extraordinary case of acromegaly in which the autopsy revealed a tumour formed of cells resembling those of

FIG. 48.—Skull of sheep, showing pituitary fossa in basisphenoid. (*R.C.S. Museum.*)

the anterior lobe of the pituitary imprisoned in the posterior part of the sphenoid; a small process of the tumour had broken through the floor of the sella and lay alongside an apparently normal gland.[2] In this case the

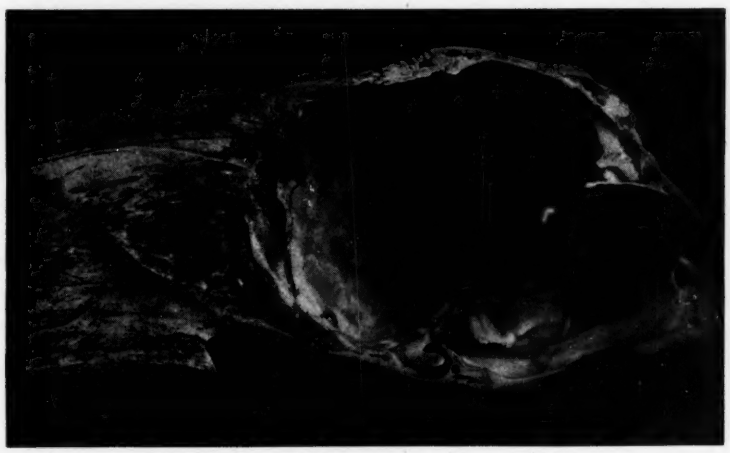

FIG. 49.—Skull of harp-seal, showing pituitary fossa entirely confined to postsphenoid. (*R.C.S. Museum.*)

sphenoidal sinus was limited to the presphenoidal region, and was not encroached on by the tumour. Clearly this unique case confirms pathologically what anatomy had already taught.

After birth the fossa grows gradually, as the contained gland and the skull-base develop. A series of radiographic photographs of the sellæ of children of average size, from 6 to 13 years (*Fig.* 52), shows that there is normally great variation in size, and that one cannot say there is any particular age at which any special increase occurs.

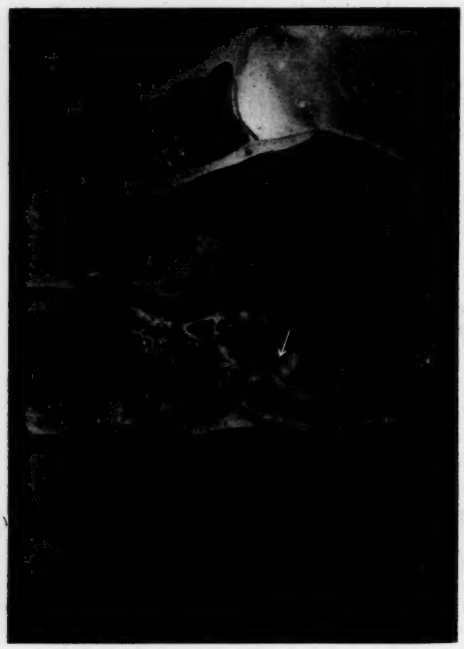

FIG. 50.—Skull of pig, showing pituitary fossa and sphenoidal sinus, with synarthrodial joint between pre- and postsphenoidal segments. (*R.C.S. Museum.*)

The pituitary fossa or sella turcica forms the narrow median segment of the middle cranial fossa. It lies at the centre of the cranial base, and is almost equidistant from the root of the nose and the posterior margin of the foramen magnum. A large number of basal fractures tear across the floor of the sella, and it may be that some of those deaths from fractured base unaccompanied by any grave hæmorrhage or cerebral laceration are the result of severe injury to the pituitary gland lying close to the site of fracture.

The shape of the fossa in sagittal section is like a U with the opening inclined slightly forwards (*Fig.* 53). This shape is masked on a lateral view by the projecting anterior clinoid process. In many dried skulls the exact shape is not so readily determined, owing to the breaking away of the dorsum sellæ which forms the posterior limit of the U. The floor is slightly concave, and is formed by the upper surface of the body of the sphenoid. It is limited laterally by a rounded ridge, just external to which is the groove which the internal carotid artery makes on the side of the sphenoidal body. Sometimes the carotid groove is lifted up by the subjacent sphenoidal sinuses, and lies almost on a level with the floor of the sella. The anterior sloping surface (*Fig.* 54) leads up to the

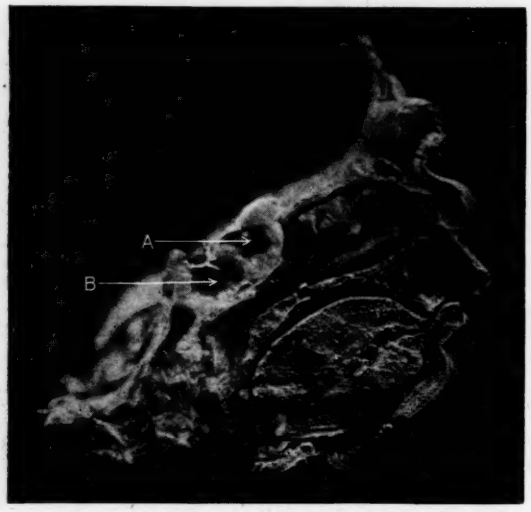

FIG. 51.—Median section of human skull about time of birth, showing craniopharyngeal canal remnant in postsphenoidal nucleus. A, Presphenoid. B, Postsphenoid with remnant of craniopharyngeal canal.

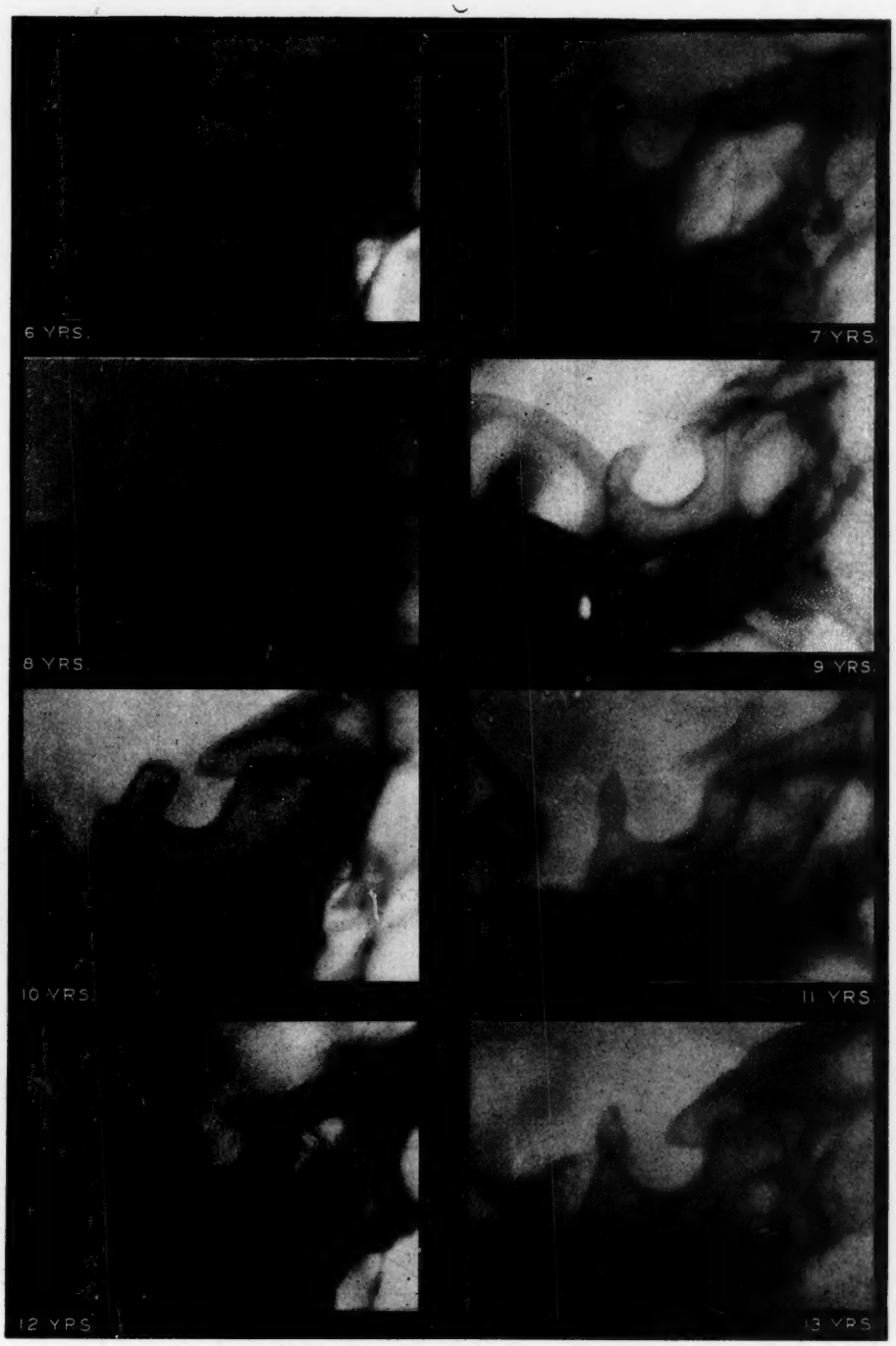

FIG. 52.—Radiograms showing size of pituitary fossa from sixth to thirteenth years.

tuberculum sellæ, just below which is sometimes seen a transverse ridge for attachment of the diaphragma sellæ. In front of the tuberculum lies the optic groove, which does *not* lodge the optic chiasma. The optic foramina are at the lateral extremities of the optic groove, and lie about 1 cm. apart.

FIG. 53.—Presphenoidal type of sphenoidal sinus. (*R.C.S. Museum.*)

Occasionally the optic groove is replaced by a smooth bulging convex surface, whilst at other times it is represented by a horizontal niche in the anterior wall of the fossa. In the latter case the limbus overhangs the fossa and increases its depth (*Fig.* 55). Such an arrangement might cause increased difficulty in approaching by the frontal route.

The three clinoid processes are not equally important. The anterior usually projects well back, and sometimes fuses with the posterior, which, as a rule, does not extend far forward from the lateral part of the dorsum sellæ. The middle clinoid process is situated laterally to the tuberculum sellæ, and is not constant. Sometimes it joins with the anterior clinoid to form a bony foramen for the internal carotid.

The size of the normal pituitary fossa varies considerably. In a series of measurements made upon over fifty skulls (from the Museum of the Royal College of Surgeons, the South Kensington Museum, and the anatomy department of St. Mary's Hospital Medical School), the average dimensions were ascertained, as follows :—

DIMENSION	MEASUREMENT	AVERAGE
Anteroposterior ..	7 to 14 mm.	10·94 mm.
Transverse ..	9 to 15 mm.	11·02 mm.
Depth	3 to 10 mm.	5·82 mm.

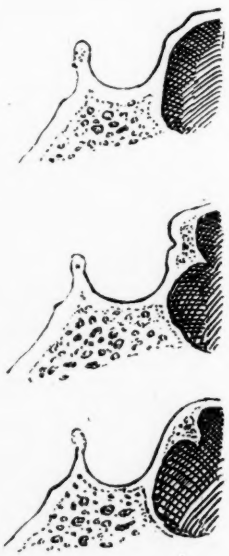

FIG. 54.—Diagrams showing variations in anterior wall of pituitary fossa.

That is, in rough measurements the fossa is 11 mm. long and broad, and 6 mm. deep.

The anteroposterior measurement was the maximum horizontal measurement

of the fossa in each case. The transverse points on which the callipers were fixed were the prominences bounding the fossa laterally and intervening between it and the carotid groove.

From a surgical aspect some other measurements are of interest, and are set forth in *Fig.* 56. These measurements agree, within two or three millimetres, with those published by Stanley Gibson.[3]

FIG. 55.—Photograph showing overhanging limbus, and exhibiting the optic groove as a horizontal niche in anterior wall of fossa.

No definite relationship seems to exist between the size and shape of the skull and those of the pituitary fossa. The distance from the temporal fossa to the sella turcica was not noted in many of the skulls, but it is less than the distance from the nasion, and averages about 50 mm.

The sella is lined by dura mater and roofed in by the diaphragma sellæ, so that the gland is hemmed in by a cuboidal box, three sides of which are bone and three fibrous. The dura is firmly attached to the anterior and posterior clinoids, but fortunately it can more easily be stripped up from the floor of the fossa and from the region of the optic groove. The lateral aspects of the fossa are closed in by the cavernous sinuses, through which travel the internal carotid arteries, the 3rd, 4th, and 6th cranial nerves, and the ophthalmic division of the 5th nerve.

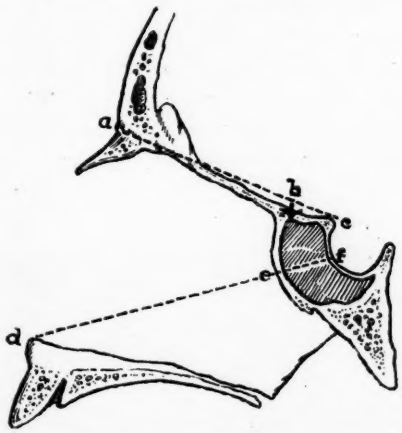

FIG. 56.—MEASUREMENTS FROM ROOT OF NOSE AND ANTERIOR NASAL SPINE TO SPHENOIDAL SINUS AND PITUITARY FOSSA.—*a b*, From root of nose to anterosuperior angle of sphenoidal sinus = 45·11 mm.; *a c*, From root of nose to anterior margin of pituitary fossa = 60·1 mm.; *d e*, From anterior nasal spine to nearest point of sphenoidal sinus = 59·28 mm.; *d f*, From anterior nasal spine to nearest point of pituitary fossa = 76·19 mm.

An anatomical fact which is not always realized when the base of the skull is examined after the brain has been removed, is that the 3rd and 4th cranial nerves, ere they entered the cavernous sinus, would be definite lateral relations to an upgrowing hypophyseal tumour. This relationship can be demonstrated easily by approaching the fossa laterally after lifting up the temporosphenoidal lobe. The 3rd nerve especially will be seen to lie in the way of approach to the pituitary body. Naturally these nerves stand a very great risk of injury in operations by the temporal route (*vide infra*).

The diaphragma sellæ is attached, not to the top of the dorsum, but along a line just below the thickened upper margin; anteriorly it is attached just below the tuberculum sellæ. The diaphragma is strong near its attachments to the bone, but becomes thin and weak as it approaches the central opening through which the pituitary stalk issues.

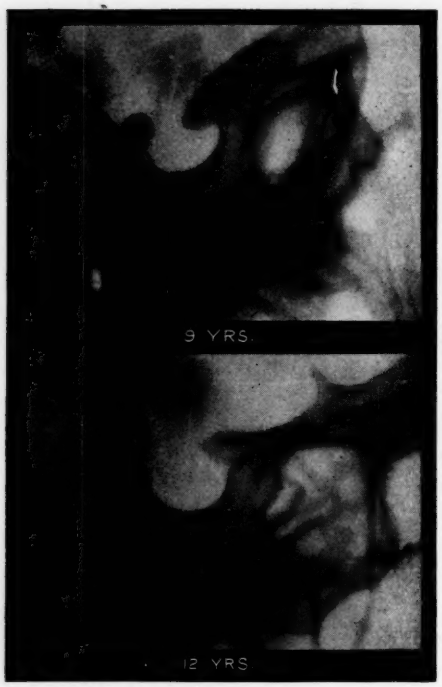

FIG. 57.—Radiograms showing presphenoidal type of sinus in children of nine and twelve years.

The relations of the fossa to the sphenoidal sinuses at different ages need to be considered in detail.

The sphenoidal sinus is very small during the first few years of life,[4] and is limited to the anterior part of that section of the bone formed from the presphenoid (*Fig.* 57). Somewhen between the seventh and the fourteenth years the sinus enlarges until the whole of the presphenoid area is excavated (*Fig.* 58). The process may stop at this stage, and many adult skulls show this arrangement. Since the pituitary fossa is formed in the postsphenoid, the sphenoidal sinus in these cases does not come into close relationship with the fossa. In the majority of cases, however, the excavation proceeds back into the basisphenoid, but the barrier between the pre- and postsphenoidal segments is frequently indicated by a transverse septum or ridge clearly visible inside the sinus (*Fig.* 59). This septum or ridge is attached to the antero-inferior aspect of the sella turcica, and in view of its frequent occurrence is worthy to be called the transsphenoidal crest or septum. When present it can be observed in *x*-ray photographs of the skull-base (*Fig.* 60).

FIG. 58.—Photograph of presphenoidal type of sinus, which has extended slightly into the postsphenoid and left a trace of transsphenoidal septum. (*R.C.S. Museum.*)

In a series of 38 radiograms of the heads of normal adult men, 22 showed the post-

sphenoidal type of sinus, 15 the presphenoidal form, whilst 1 represented an intermediate stage; 9 of the postsphenoidal sinuses gave definite indication of a trans-sphenoidal crest or ridge. Of the 61 dried skulls which I examined, 14 showed indication of a trans-sphenoidal ridge. Since the crest is thus shown to be present in dried preparations and by *x* rays in the living in about the same proportion (1–4) of all sinuses, it is evident that the radiographic appearances are of value in enabling the surgeon to estimate the presence or absence of that feature of the internal structure of the sphenoidal sinus.

In the pig, whose sphenoidal sinuses are well developed, there is a synarthrodial joint between the pre- and postsphenoid; but the backward-growing air sinus bursts through this joint to one or other side of the mid-line and proceeds to excavate the postsphenoid. This process may occur in such a way that the whole basisphenoid is hollowed out by a prolongation of one sinus; in such a case the opposite sinus is small and almost confined to the presphenoid.

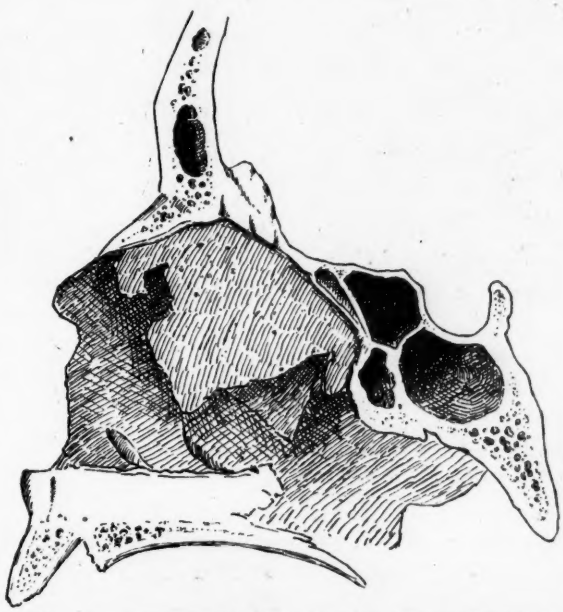

FIG. 59.—Drawing of skull, showing trans-sphenoidal septum. (*R.C.S. Museum.*)

Many indications of a similar process are to be observed in human skulls, and it is possible that many of the curiously and markedly deviated sphenoidal septa consist of two parts—a median intersphenoidal portion and a trans-sphenoidal element. For example, in a skull examined at the South Kensington Museum, the presphenoidal part of the septum is median, whilst the postsphenoidal portion deviates to the left, a condition explained by the absorption of the right half of the trans-sphenoidal and the posterior portion of the median septum. Traces of the lateral portions of the trans-sphenoidal septum can be seen very frequently in the form of a vertical or oblique bony buttress attached opposite the carotid groove. This process might well be called the carotid buttress (*Fig.* 61). It is often present when no median trace of trans-sphenoidal crest remains.

In quite a large number of cases the excavation of the sphenoid is so complete as to absorb totally the cancellous tissue and leave no trace of trans-sphenoidal crest or septum; there is then a scaphoid-shaped sinus into the roof of which the sella turcica bulges (*Fig.* 62). The varying relation of the pituitary fossa to the sphenoidal sinus is shown in the accompanying diagrams (*Fig.* 63). It will be seen that the pituitary fossa often causes no

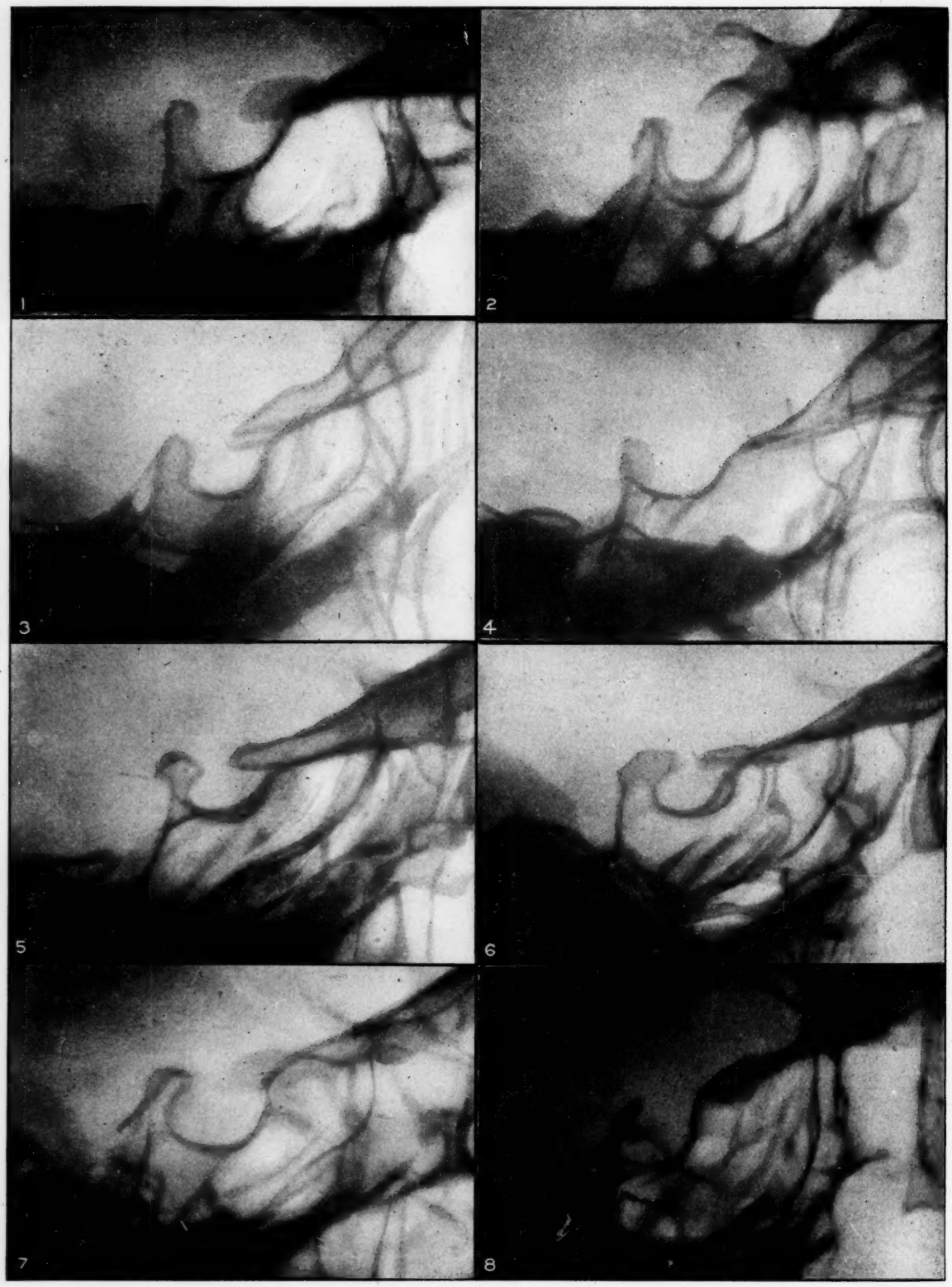

FIG. 60.—Radiograms of eight normal adult males (between twenty and thirty years of age). In the last two the trans-sphenoidal crest can easily be seen.

bulge into the presphenoidal type of sinus, and if it does it is in the posterosuperior angle of the sinus; whilst in the postsphenoidal type the bulge is always present, but is on the roof of the sinus. Any attempts to open up the posterosuperior wall of the latter type would cause injury to the clivus, and exposure of the crura cerebri.

The relationship of the median intersphenoidal septum to the fossa is not constant. Its posterior attachment is frequently to one side of the middle line, so that a surgeon taking it for his guide might open into the cavernous sinus. This fact renders the frequent bulge of the internal carotid artery into the sinus of greater significance, though it is perhaps unlikely that such a bulge would be mistaken for the sella.

FIG. 61.—Photograph showing trans-sphenoidal crest and lateral portion of trans-sphenoidal septum —the 'carotid buttress.'

The sphenoidal sinus nearly always reaches up immediately in front of the fossa to the optic groove and jugum sphenoidale, thus lying immediately underneath the posterior part of the floor of the anterior cranial fossa. In some cases, indeed, the optic nerves form a well-marked bulge into the sinus, and there may in fact be a supra-optic recess. Occasionally the posterior ethmoidal cell insinuates itself above the sphenoidal sinus and comes into relationship with the anterior part of the sella turcica, a condition which has occasionally caused surgeons to miss the direct way to the sella.

FIG. 62.—Postsphenoidal type of fossa. (*R.C.S. Museum.*)

In rare cases the sphenoidal sinuses remain rudimentary, and then a thick portion of cancellous tissue will intervene between the nasal fossa and the sella turcica.

Base of the Brain.—Above the tentorium sellæ lies the large subarachnoid space (cisterna basalis), which separates the structures in the interpeduncular space from the base of the skull. Through this gap, which is filled with cerebrospinal fluid, the stalk of the pituitary courses backwards

and upwards to reach the floor of the third ventricle, which lies well above the fossa.

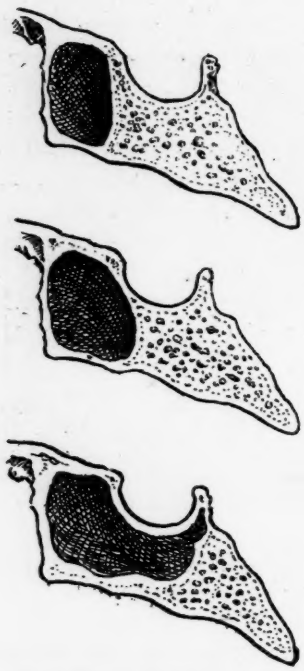

FIG. 63.—Diagrams showing variations in the relationship of the pituitary fossa to the sphenoidal sinus.

The optic chiasma lies slightly behind the sella turcica at a height of about one centimetre above the diaphragma sellæ (*Fig.* 64). As the optic nerves diverge from the chiasm to reach the optic foramina, they cross the roof of the fossa, and leave a triangular gap between them and the anterior limit of the fossa through which the anterior part of the pituitary body is visible. A gap of 10 mm. or more separates the optic nerves as they enter the orbits. For any pressure or traction to be exerted on the optic chiasma by a tumour growing from the sella, the growth would have to protrude well out of the fossa. On anatomical grounds one would expect the anterior aspect of the chiasm to be the first part to suffer pressure from an upgrowing pituitary tumour.

Close to the posterior aspect of the dorsum sellæ and the clivus are the crura cerebri; tumours breaking the bounds of the fossa would soon press against these structures. The clivus is frequently separated from the sphenoidal sinuses by the merest shell of bone; indeed specimens are to be found in which part of this shell of bone is wanting, and a direct connection exists between the sphenoidal sinus and the posterior fossa of the skull.

The vascular relations of the fossa are simple but important. It is surrounded by a venous and surmounted by an arterial circle. The venous circle is formed by the two cavernous and the anterior and posterior intercavernous sinuses. On at least one occasion the anterior intercavernous sinus has been reported as enlarged in a case of hypophyseal tumour. The sinuous way in which the internal carotid artery courses through the cavernous sinus is well known; just above

FIG. 64.—Sketch from specimen, showing relation of optic chiasma to pituitary fossa in child soon after birth. (*R.C.S. Museum.*)

the fossa it breaks up into the anterior and middle cerebral arteries, which take part in the formation of the circle of Willis. That arterial circle thus surrounds the upper aperture of the fossa (*Fig.* 65), and its exact relations can be judged by a glance at *Fig.* 66, which is taken from a specimen in the Museum of the Royal College of Surgeons. One can readily see how any pituitary growth ascending from the fossa would enter the arterial circle, and would be embraced more tightly in proportion as it increased in size. Moreover it will be observed that the optic nerves lie beneath the anterior part of the circle, so that as the optic chiasma is pushed up by a tumour, the optic nerves will gradually be dragged on and strangled between the neoplasm and the arteries. Post-mortem accounts confirm this occurrence, and show that the circle of arteries may clasp the tumour just as would a piece of string tied tightly round it (*Fig.* 67).

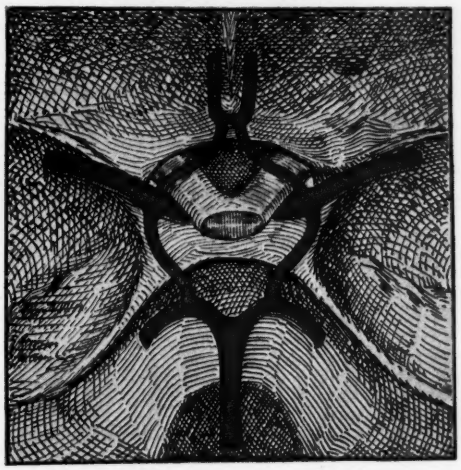

FIG. 65.—Diagram showing the relation of the circle of Willis to the pituitary fossa.

FIG. 66.—Photograph of specimen, showing the relations of the circle of Willis to the base of the skull, the optic chiasma, and the pituitary gland. (*R.C.S. Museum.*)

PATHOLOGICAL CONSIDERATIONS.

The bony and dural limits of the fossa offer considerable resistance to any increase in size of the gland, so that any alteration in contour is of significance. Any marked deviation from the normal can readily be detected in the living subject by the *x* rays. The abnormal fossæ may be classed in three groups: (1) *Enlarged fossæ with contour not deformed;* (2) *Fossæ smaller than usual;* (3) *Deformed fossæ.*

1. Enlargement may be due to adenomatous overgrowth of the anterior part of the gland, to malignant neoplasm originating in the fossa, and possibly to repeated physiological enlargement resulting from increased functional activity, as may occur in pregnancy.

Many cases of acromegaly furnish fossæ of this type, in which all the diameters are enlarged. Fearnsides[5] identifies a special type of fossa, having an anterior and posterior bulge, with acromegaly. Though this form is not constant in the disease, its occurrence is interesting, since the spot where the fossa does not so readily atrophy and enlarge corresponds to the site of the trans-sphenoidal crest, i.e., the strongest part in the floor of the sella. A marked thinning of the bony walls occurs, and in dried specimens the thinned dorsum sellæ is generally missing.

The inter-relation between the thyroid and the pituitary is suggested by the undoubted enlargement of the fossa in cases of cretinism (*Fig.* 68 A). Again, in that curious disease, achondroplasia (*Fig.* 68 B), the sella is sometimes considerably enlarged in a symmetrical manner, and the fact that in such patients the skull-base is prematurely ossified, adds significance. In

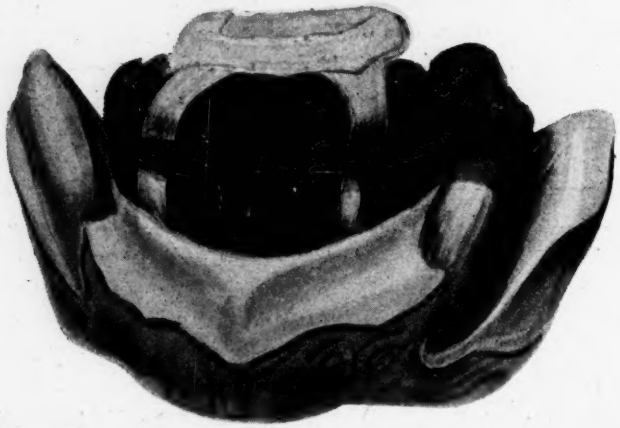

FIG. 67.—Showing how a pituitary tumour becomes clasped by the circle of Willis, which thus compresses the optic nerves. (*After Hirsch. The original is uncoloured.*)

view of the skeletal changes commonly associated with pituitary derangement, it is interesting to note that in osteitis deformans there is no enlargement of the sella, but only a thickening of the clinoid processes and dorsum (*Fig.* 68 C).

There are other less common causes of sellar enlargement. Hirsch[6] states that "demonstrable enlargement of the sella . . . can be caused by other processes, such as general or localized hydrocephalus, chronic circumscribed meningitis, and tumours of other parts of the brain." One case under my care had the fossa enlarged in consequence of chronic syphilitic meningitis (*Fig.* 68 D).

2. Very small fossæ are seen in connection with those cases of hypopituitarism which are associated with imperfect development of the gland. The accompanying radiogram (*Fig.* 68 E) showing a very small fossa was taken from a well-marked case of dystrophia adiposogenitalis, under the care of Dr. Langmead. In some cases of so-called idiopathic epilepsy, the fossa is smaller than normal (*Fig.* 68 F), and accompanied by marked approximation of the clinoid processes (Castellain).

3. The fossa may be deformed (*a*) by tumours bursting from within, or (*b*) by interpeduncular neoplasms pressing down from above (see *Figs.* 70, 71).

(*a*) We must here for a moment consider the nature of the tumours which affect this region, and note their size and relations when met with in operations.

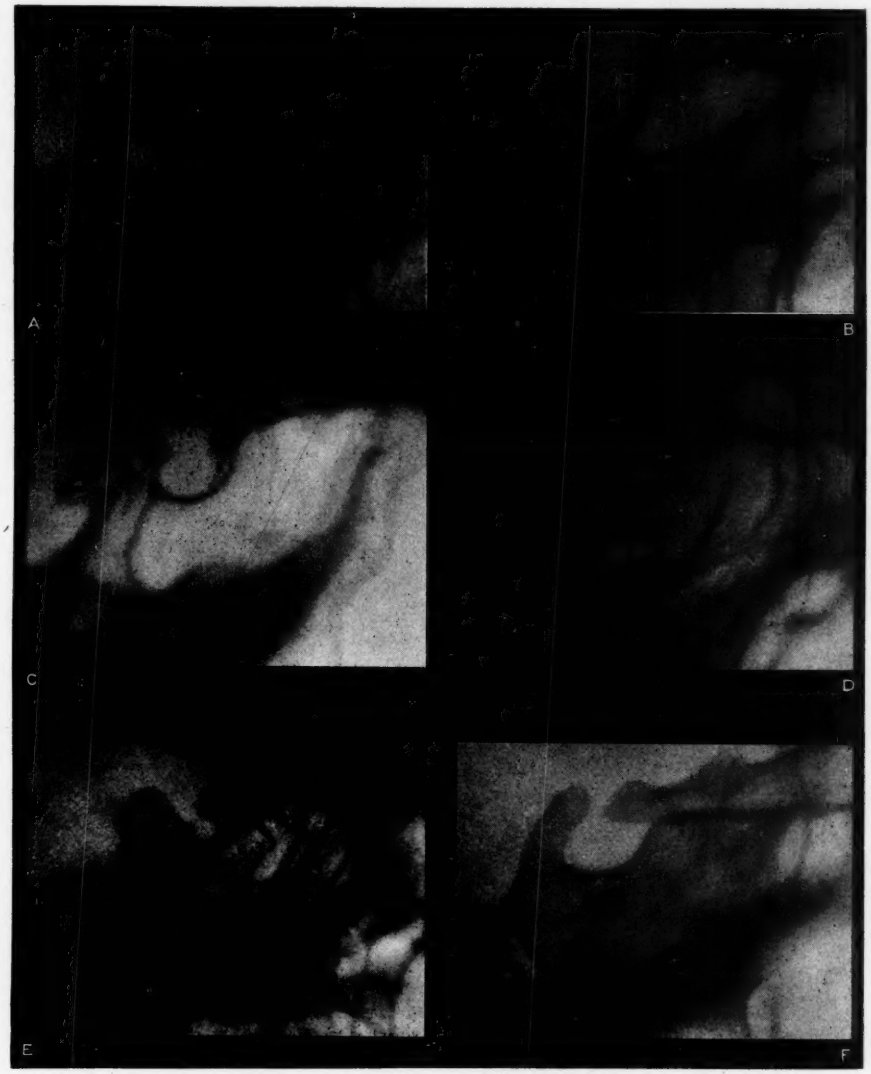

FIG. 68.—RADIOGRAMS OF PATHOLOGICAL PITUITARY FOSSÆ.—(A) Cretinism; (B) Achondroplasia (age 17); (C) Osteitis deformans; (D) Chronic syphilitic meningitis (*Case* 2 of author's); (E) Hypopituitarism (Dr. Langmead's case of dystrophia adiposo-genitalis); (F) Epilepsy.

An examination of 64 cases published by Cushing,[6] Hirsch,[7] and von Eiselsberg,[8] in which the microscopical pathological diagnosis is mentioned, shows the interesting fact that the majority of hypophyseal tumours are

adenomata. Of Cushing's 26 verified cases, 20 were chromophobe strumae or adenomata. Out of 16 cases operated on by von Eiselsberg, 8 showed an adenomatous growth, whilst 17 out of Hirsch's 22 verified tumours were proved to be adenomata. Thus at least 45 out of the 64 tumours were adenomata. It is probable that several more of von Eiselsberg's tumours were adenomata, since the varied diagnoses made in his first 7 cases, which did not include a single adenoma, contrast strangely with the last 9 cases, where 8 were proved to be adenomata. It is quite clear that great confusion existed (and still exists in some quarters) as to the proper name to be given to the common enlargement of the pituitary. Probably an explanation in von Eiselsberg's case is forthcoming in the fact that he visited America after his sixth case, and would then learn from Professor Cushing himself the true nature of the majority of pituitary tumours. If we take only Cushing and Hirsch's cases, 37 out of 48 were due to adenomata, i.e., 75 per cent.

Of the 64 cases mentioned above, 7—i.e., 11 per cent—proved to have cysts, sometimes filled with a yellow fluid containing cholesterin crystals. Other tumours have been certified as endothelioma, teratoma, mixed tumour, calcifying chondroma, epithelial cancer, or sarcoma.

There is some ground for thinking that some of the cysts are really due to the complete degeneration of an anterior-lobe adenoma. Thus, the fluid of some, on microscopic examination, shows merely cholesterin crystals; in others epithelial cells and débris are also seen, though no tumour tissue is obtainable; whilst in a case related by Hirsch, fluid of a similar nature was accompanied by tumour tissue consisting of eosinophilous hypophyseal cells.

The more carefully the pathological diagnosis has been made, the less frequently has the term cancer or sarcoma been applied to the tumour, and it is evident that malignant disease of the pituitary body must be accounted comparatively rare. Interpeduncular tumours of a malignant nature are probably more common.

Remembering that the anterior lobe of the pituitary, and the thyroid gland, are both developed as outgrowths from the primitive pharynx, our attention is at once arrested by the prevailing type of neoplasm arising in them both. The commonest tumour of the thyroid is an adenoma which frequently becomes cystic (though the cyst does not contain cholesterin crystals) and comparatively seldom undergoes malignant change. The adenomata of both glands cause more trouble by local pressure than from the risk of malignant change.

A question of importance to surgeons refers to the size which pituitary tumours attain before causing marked symptoms. Most operations are advised on account of: (1) Symptoms due to local pressure, especially upon the optic chiasma; (2) Symptoms due to general increase of intracranial pressure.

It requires no argument to prove that, for a pituitary tumour to cause increase of the general intracranial pressure, it must project well into the cranial cavity; and remembering the relation of the chiasma to the fossa, it is equally clear that visual disturbances indicate a considerable intracranial extension of the growth. Not only is the chiasma 1 cm. above the fossa, but considerable pressure seems to be needed to cause optic symptoms. An

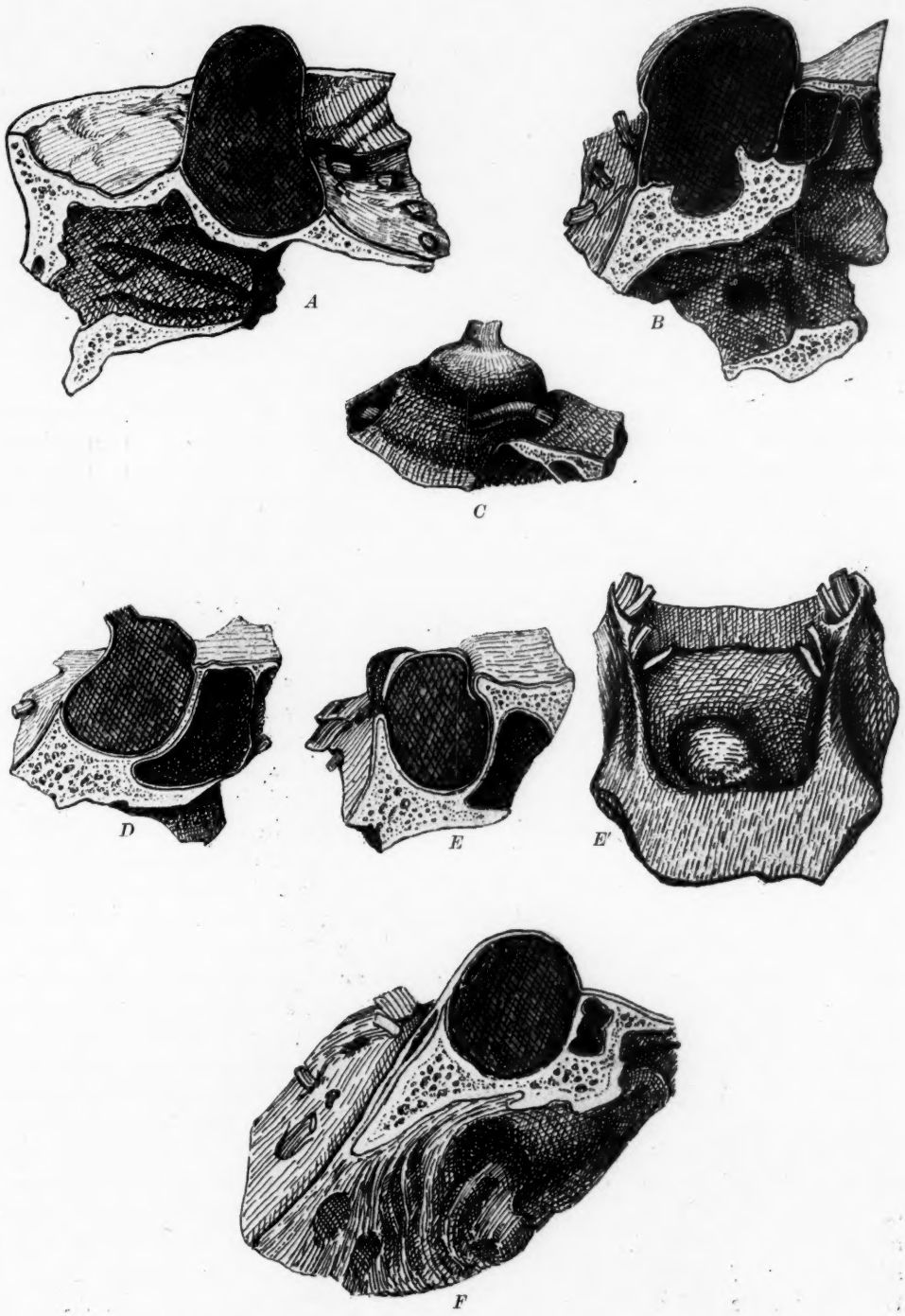

FIG. 69, *A*, *B*, *C*, *D*, *E E'*, *F*.—Drawings showing the way in which tumours of the pituitary gland generally grow upwards quite early. (*After Schloffer.*)

interesting light is thrown on the point by a case operated on for symptoms of acromegaly by Bogoiavlensky,[9] who adopted the frontal route. He states that after lifting up the frontal lobe, "one then perceived in front of the optic chiasma a tumour about the size of a cherry, occupying the entire space between the optic nerves, compressed from above downwards, and projecting forward in a tongue-like process." In spite of this mass projecting upward and forward, and certainly pressing against the chiasma, the patient had no visual disturbances. It seems certain, therefore, that every case with visual symptoms must have a considerable intracranial extension of the growth. I have searched the literature of pituitary operations fairly thoroughly, and have not yet found a case with optic symptoms, in which verification at operation or autopsy was permitted, which did not show a large intracranial extension. We conclude, therefore, that *all pituitary tumours which come to operation for symptoms other than acromegaly have long before burst the bounds of the fossa.*

Exactly the nature of the deformation of the fossa probably depends considerably on the rate of growth of the neoplasm. A slowly-growing tumour would be more likely to cause a thinning of the walls of the fossa and a gradual stretching of the diaphragma sellæ. A rapidly-growing tumour would more probably burst through the dural covering before much erosion of the fossa walls had occurred. The first part of the surrounding walls to give way is almost always the dural roof, which has a weak central portion traversed by the pituitary stalk. Calling to mind the usual shape of the fossa, it will be seen that the tumour will advance upward and forward (*Fig.* 69), and the first suprasellar projection should be *in front of the optic chiasma.* In this way pressure may first be exerted on the anterior fibres of the chiasma. The above related case of Bogoiavlensky's illustrates this point.

A statement by Bartels[10] is in apparent contradiction to this view. He asserts: "When the tumour arises from the hypophysis in the sella, it extends chiefly behind and under the chiasma. In 39 cases in the literature, I have only found four with extension in front of the chiasma. The tightly-spanned diaphragma sellæ surely opposes a hindrance to the forward growth of the hypophyseal tumour. I could believe that the tuberculum sellæ would not easily allow a tumour to grow forwards." This statement, made in 1906, is so directly contrary to my observations, that an explanation must be sought. A key to the problem is not difficult to find. An examination of Schloffer's diagrams and other illustrations of pituitary tumours in varied stages of growth, makes it clear that growth of the tumour is upwards and forwards in the triangular gap between the chiasma, optic nerves, and anterior margin of the fossa. But so soon as the tumour has broken well out of its prison, it more readily spreads backwards, while at the same time further forward growth may be hindered by the anterior part of the circle of Willis. When once the dorsum sellæ is eroded, extension would nearly always be backwards. Thus Bartel's assertion must have been made after study of advanced tumours, and is not necessarily contradictory of the view here put forward, that the early growth is always in front of the chiasma.

The dorsum sellæ and the anterior and posterior clinoid processes are

stronger and more resistant, but gradually become eroded by a steadily growing tumour (*Fig.* 70). The lateral *x*-ray outline of the dorsum sellæ may be retained, owing to the persistence of the posterior clinoids and the thick lateral portions of the dorsum, even though the thinner mid-portion be totally absorbed. Writers have sometimes described the 'pushing back' of the dorsum by a growth. I have seen no evidence of such a movement. Even when the dorsum is extremely thin, it preserves its original direction until it is obliterated or absorbed. This suggests that new bone is not so readily formed under the stimulus of the tumour growth in this situation.

The fossa assumes a cup-shaped outline at a certain stage of erosion, whilst later, all traces of original shape may be banished (*Fig.* 71).

Sometimes the antero-inferior wall of the fossa is eroded and the sphenoidal sinus opened by an advancing neoplasm, though this never occurs before the endocranial extension has taken place. More frequently the bulging of the sella into the sinus is accentuated; as the sellar floor is thinned,

FIG. 70.—RADIOGRAMS OF DEFORMED FOSSÆ.—(A) Case under Sir J. Broadbent with symptoms of acromegaly and oncoming blindness; (B) Pituitary fossa operated on by author for cyst in case of Winning (author's *Case* 2); (C) Fossa in a case of endothelioma arising in region of the pituitary gland (author's *Case* 1).

more bone is formed, so that ultimately only a few millimetres may separate the sella from the anterior sphenoidal wall. In no other way can we explain the common experience of operators who meet a thinned bony sellar floor immediately on opening the sinus.

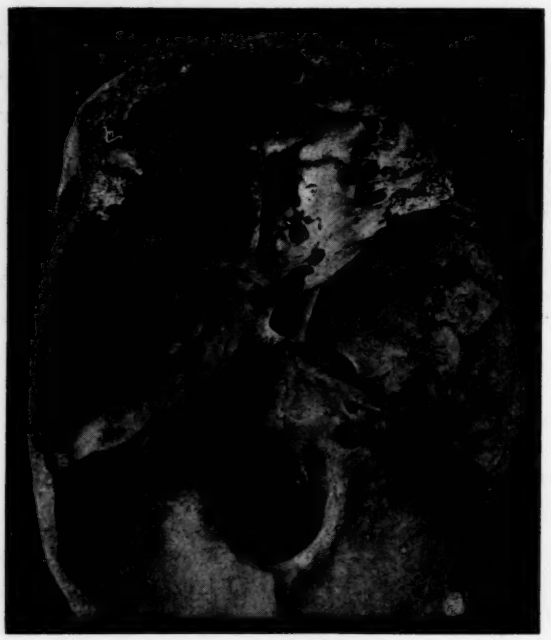

FIG. 71.—Photograph of deformed pituitary fossa. The roof of the sphenoidal sinus has been eroded. Part of the median intersphenoidal septum remains. (*Skull in St. Mary's Hospital Museum.*)

By comparing *x*-ray pictures taken during life with post-mortem records, we may conclude that if the dorsum sellæ or anterior or posterior clinoid processes are obliterated or markedly eroded, there must be a large intracranial extension to the tumour. The same holds good if the growth has burst into the sphenoidal cells.

b. Interpeduncular tumours gain a considerable size before their downward pressure causes erosion of the dorsum sellæ and the clinoids. Later, a total obliteration of the confines of the gland may result, but sometimes the main outline and size of the fossa remain fairly normal, whilst the upper aperture appears larger than normal.

THE PROBLEM OF SURGICAL APPROACH TO THE PITUITARY FOSSA.

Indications for Operation.—The symptoms due to pituitary tumour which may call for operation may be classed in three groups:—

1. Symptoms due to increased intracranial pressure, e.g., headache, mental changes, etc.

2. Local pressure symptoms, especially affecting the optic chiasma or tract.

3. Metabolic disorders due to derangement of the glandular secretion.

By far the most common indication, indeed the only one apart from increased intracranial pressure for which most people would be willing to undergo an operation with a seven per cent mortality, is oncoming blindness due to pressure on the optic fibres. It is greatly to be regretted that so many patients are now permitted to go almost blind before operation is advised. By the time that general intracranial pressure symptoms are marked the tumour must have reached a great size, and decompression either by the temporal or the fronto-orbital route is imperative if the patient is to have relief.

Operation has been performed for acromegaly and for dystrophia adiposo-genitalis, but seldom unless there has been some evidence of pressure in

addition. We doubt very much whether in the future it will be accounted wise to operate for uncomplicated acromegaly.

Methods of Approach.—It is reported that only a few years ago a famous surgeon remarked that it was tempting Providence to operate in the region of the hypophysis; and if we consider the comparative inaccessibility of the fossa, and reflect that until recently our knowledge of the functions of the hypophysis was very vague, it is certainly no matter for surprise that this has been one of the last parts of the body to be explored by the surgeon. The last decade, however, has witnessed the birth and development of hypophyseal surgery, and now that many methods have been tried and records published, the time has come to survey these experiences and, if possible, draw some conclusions for future guidance.

All over the world Horsley[11] is recognized as the pioneer of pituitary surgery. He followed his experimental investigations, published in 1886, by suggesting to Paul,[12] of Liverpool, an operation for approaching the gland (in 1893); and although this was not fully carried out, it raised the question of the feasibility of the operation. Horsley himself operated on one case certainly as early as April, 1904, and possibly still earlier than this; but every writer on this subject has had to regret that this noted operator has not published full details of his cases. Horsley adopted a route through the temporal fossa, and had already done nine such operations by 1906.

Meanwhile others were considering different methods of approach. In 1900 König[13] published his views favouring a transpalatal approach, whilst Loewe[14] and Kocher[15] devised methods of resection of the upper jaw and palate in order to obtain sufficient room to reach the fossa through the sphenoidal cells. In 1904 Kiliani[16] experimented on the cadaver, and outlined an extensive operation in which a large bilateral frontal bone-flap was reflected, the dura opened, the longitudinal sinus ligated, and the frontal lobes elevated.

Krause,[17] who in 1900 removed a bullet from the chiasmal region by utilizing a frontal bone-flap, in 1905 removed a large tumour from the neighbourhood of the pituitary fossa by the same method. He reached a depth of 10 cm., but the patient did not survive.

In 1906 a great impetus was given to the quest of a suitable route of approach by Schloffer's article,[18] in which he considered critically the various proposed operations. In the succeeding year he operated successfully by the nasal route on a patient with bitemporal hemianopsia. Quickly succeeding the publication of this case, a multitude of modifications of the operation by the nasal route were developed, all of which had as a basis a partial or complete removal of the nasal septum, turbinate bones, ethmoidal cells, and sometimes even the anterior walls of the frontal sinus. Approach to the nasal cavity was often furthered by splitting or reflecting the nose.

In 1909 Kocher adopted a submucous resection of the septum for approaching the sphenoid, and in the following year Hirsch perfected the endonasal submucous operation, which has now, with slight modifications, been performed successfully on a large number of cases.

The need for an aseptic route has recently caused a revival of the approach direct through the cranium in the frontal region, extra room being gained by depressing the eyeball after removal of the orbital roof.

The pituitary fossa has, therefore, been arrived at directly through the cranium and indirectly through the facial skeleton. The following scheme shows the routes that may be utilized (*Fig.* 72) :—

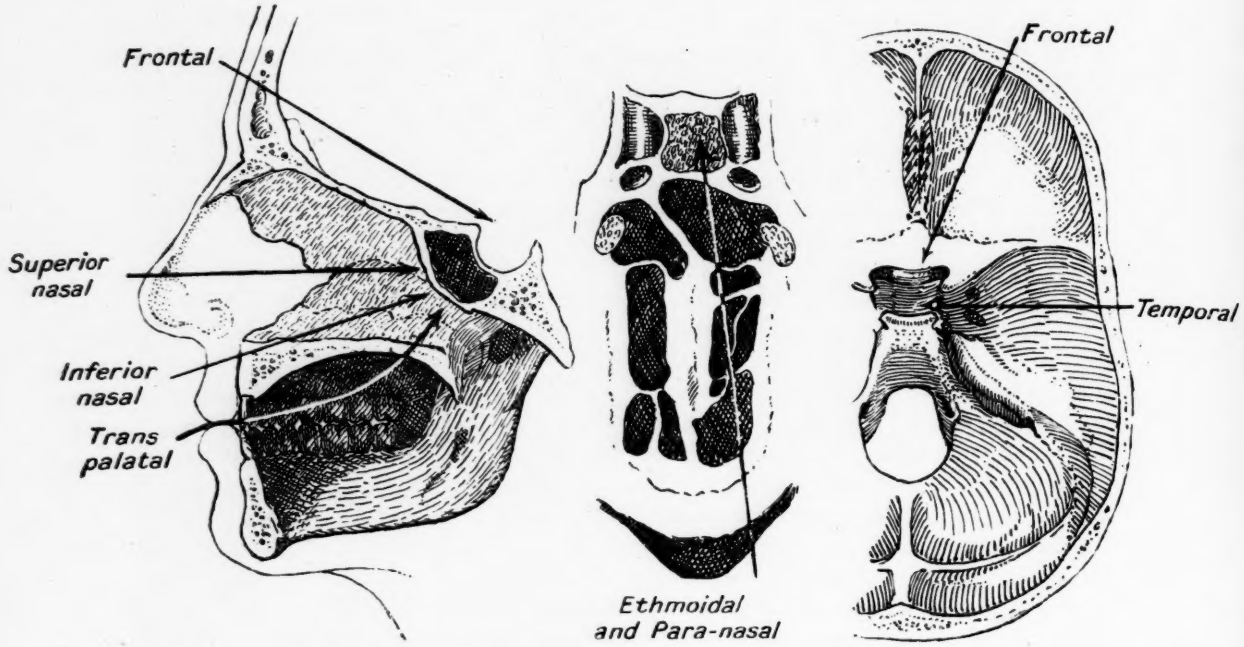

FIG. 72.—Diagrams indicating routes of approach to the pituitary fossa.

CRANIAL.		
Temporal (intradural)		Horsley
Temporal (extradural)		Braun[19]
Frontal		Krause
Fronto-orbital		Frazier[20]
Callosal puncture.		
FACIAL.		
Nasal	Septal resection	Schloffer
		Cushing
		Hirsch
		West[21]
		Citelli[22]
		Kanavel[23]
		Halstead, etc.[24]
	Ethmoid resection	Hirsch
Paranasal		Chiari,[25] Kahler[26]
Palatal		König (Preysing)[27]
Maxillary		(Bourget and Dansan)[28]
Suprahyoid pharyngotomy		(Experimental only).

The region immediately above the pituitary fossa may be reached by trephining the vertex and puncturing the corpus callosum, but though this method has been useful in relieving general pressure symptoms, it is impracticable as a route of approach for the removal of a tumour.

There are only four of these methods which have been practised on a sufficient number of cases to merit special attention. These are Horsley's temporal method, Schloffer's coarse nasal operation, Hirsch and Cushing's submucous septal approach, and Frazier's fronto-orbital method.

Though Horsley has never published the details of his cases, one has gathered the following facts from those who have seen him operate, and from the accounts of four pituitary cases operated on by him mentioned in Tooth's classical paper on brain tumours.[29] Horsley operates in two stages, in the first making a temporal bone-flap, and in the second incising the dura, lifting up the temporal lobe, and exposing the lateral aspect of the pituitary body. Of the four cases referred to above, one died six hours after the operation without recovering consciousness; another developed hemiparesis and hemianæsthesia after the second stage of the operation; whilst in a third case the operation caused motor aphasia lasting some time. Paralysis of the muscles supplied by the 3rd cranial nerve followed two of the operations. Certainly the distance from the temporal fossa to the sella turcica is the shortest possible route of approach: but the temporal lobe has to be dislocated very seriously, and unless the tumour peeps over the cavernous sinus, it would almost be inaccessible. Cushing found the method impracticable in human beings, although easy in dogs. Horsley said in 1906 that he had had 2 deaths in 10 cases.

FIG. 73.—Incision in von Eiselsberg's operation.

There are very many modifications of Schloffer's method, which agree, however, in these points: an approach is gained to the nasal cavity, either directly through the anterior nares, or by reflecting the nose downwards, upwards, or to one side, or by splitting it in various ways, or by a sublabial incision; varying portions of the nasal septum and lateral walls of the nasal fossa are removed to furnish more room; the sphenoidal sinus is opened, and through it the pituitary fossa is approached. Von Eiselsberg's technique[8] may be taken as an example (*Figs.* 73–76), since he has performed the operation more often than any other surgeon. The posterior nares are plugged by Belloc's method, and the threads brought through the right nostril and the mouth, and then over the lip. An incision is made along the left nasolabial furrow round the left ala nasi, and continued up to the root of the nose and as far as the glabella, a small transverse continuation going as far as the inner canthus of the right eye. The incision cuts through the whole thickness of the skin. The nasal bone is cut through with bone forceps or chisel. Then the philtrum is cut through, and the anterior part of the septum severed in such a way that a large piece of the cartilage and vomer remain attached to the reflected nose. This technique is supposed to prevent a sinking in of the nose afterwards. The whole external nose is now reflected to the right, and either retracted or fixed to the

cheek by a suture. The turbinated bones and the rest of the nasal septum are now removed, without disturbing the mucous membrane between the turbinates, the last part of the vomer and the rostrum of the sphenoid are taken away, and the sphenoidal sinus is opened. The radiogram is now fre-

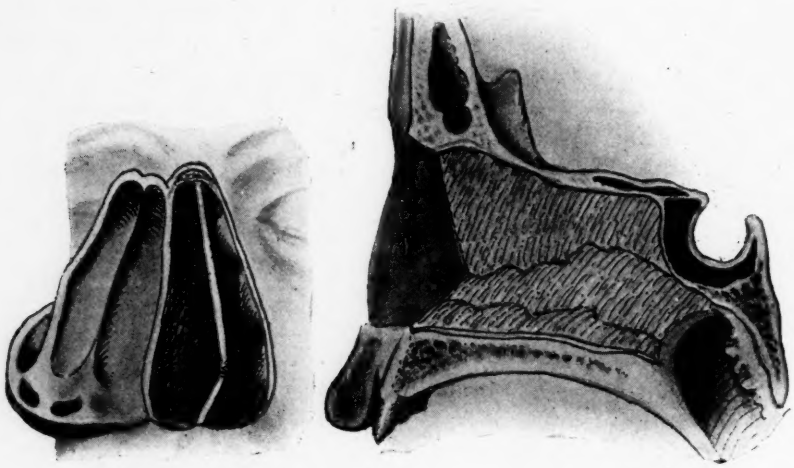

FIG. 74.—Schloffer's operation. Stage 1. (*After von Eiselsberg.*)

quently consulted, and the distance of the sphenoidal sinus from the glabella estimated, and compared with the dimensions in the patient. After removal of the anterior and under portion of the wall of the sphenoidal sinus, the mucous membrane lining the sinus is carefully removed with a sharp spoon

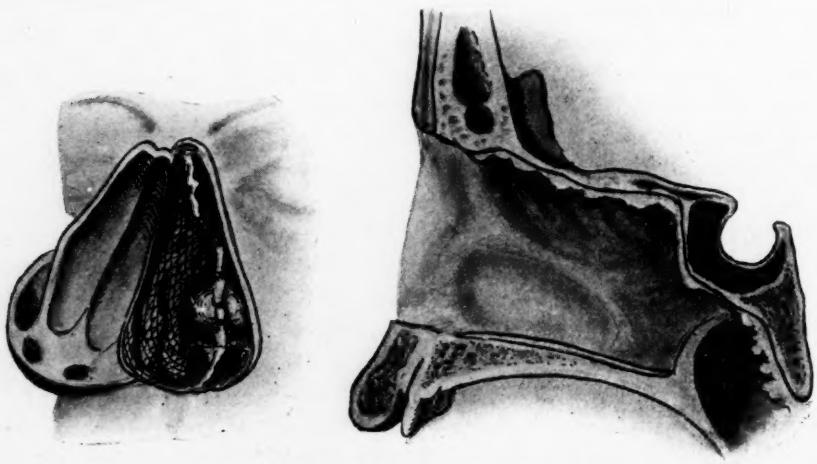

FIG. 75.—Schloffer's operation. Stage 2.

and raspatory, whereby the swelling caused by the pituitary fossa is brought clearly into view in the upper and posterior portion of the sinus. The swelling is carefully broken into by a chisel and the hypophysis exposed. The opening is enlarged by the aid of a sharp spoon or small chisel, or a punch forceps.

After incision of the dura mater, one generally sees a pulsating swelling (especially when it is cystic). By the aid of a sharp spoon, as much of the tumour as can easily be removed without going too deeply in towards the brain is now taken away. An isoform gauze strip is passed through a drainage-tube of medium size, and a portion 4 cm. long is allowed to project from the end. This projecting piece of gauze is laid on the pituitary fossa, and the lower end of the tube sewn to the skin at the left nasal aperture. The nasal cavity is now swabbed and inspected, and if there is no more bleeding the Belloc's plug is removed. The nose is then stitched back in its place. The operation takes one to one and a half hours.

In the year 1912 von Eiselsberg had performed sixteen operations by the Schloffer method. Five of these cases developed meningitis after the operation

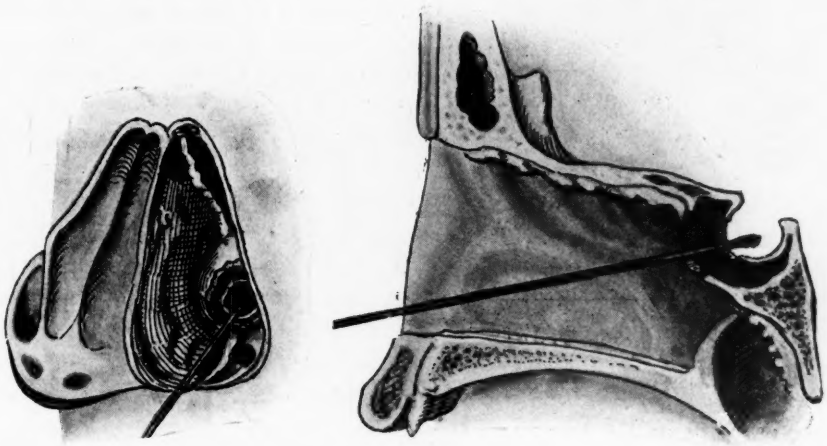

FIG. 76.—Schloffer's operation. Stage 3.

and four succumbed to the meningeal infection. Since this operator has had better results than the average, the outlook would not be promising if there were no better method, such as is provided by either of the next two operations to be described.

Before discussing the advantages and disadvantages of this operation, we will describe Cushing's and Frazier's operations. Hirsch and Cushing's submucous septal approach is really one of the most ingenious in the whole range of surgery. For those who are interested in the development of an operation, the history of the transition from Schloffer's coarse operation to Cushing's refined method is worth recording. Schloffer's first operation, based upon the experimental work of Giordano, was carried out on March 16, 1907. In this first operation, the inner wall of the left orbit, the inner wall of the antrum of Highmore, and part of the nasal process of the superior maxilla were removed, in addition to the structures mentioned in von Eiselsberg's account. Hochenegg,[30] in his first operation, on February 14, 1908, plugged the nasopharynx, and added to Schloffer's method the resection of the frontal sinuses. On January 9, 1909, Kocher made a distinct advance by splitting the nose transversely and approaching the pituitary fossa by a *submucous*

resection of the septum. Early in 1909, Kanavel outlined an inferior nasal approach by reflecting the external nose upwards and resecting the septum. This method was not published or practised by its originator till November, 1909; but prior to that Halstead, who knew of and was interested in Kanavel's work, improved on his method in an operation performed on July 21, 1909, by making an incision under the upper lip and then elevating the nose and resecting the septum. On December 27, 1909, Mixter[31] adopted Kanavel's inferior nasal route, but performed *submucous* resection of the nasal septum. In 1910 Cushing utilized a sublabial incision with submucous resection of the septum. Hirsch performed his first endonasal operation (without any reflection of the nose) on March 10, 1910; this was by his ethmoidal route. Three months later he operated by a submucous septal method. One of the most striking coincidences in surgery is that Cushing and Hirsch independently operated for the first time by the submucous septal resection method on the same day, June 4, 1910. It is one more evidence of the international nature of scientific knowledge. An examination of Cushing's published operations is interesting as showing how the various operations were gradually evolved.

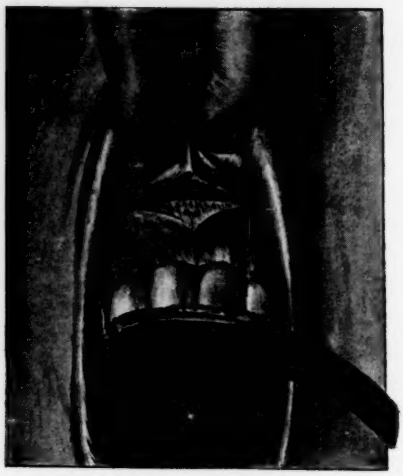

FIG. 77. — Cushing's operation. Stage 1. (*Modified from illustrations published in the Weir-Mitchell Lecture*, 1914.)

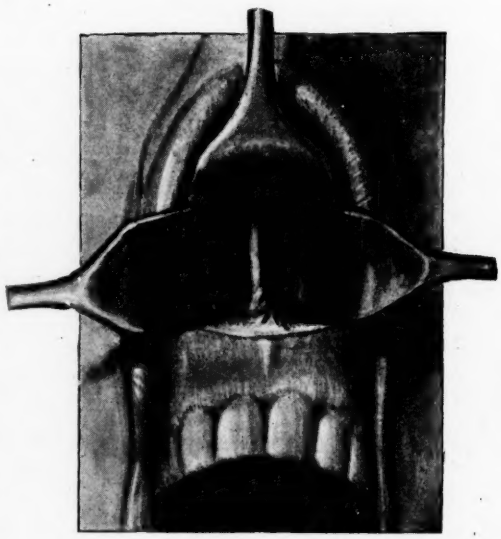

FIG. 78.—Cushing's operation. Stage 2.

Cushing's perfected technique is as follows: By using intratracheal insufflation as the method of anæsthesia, the need of plugging the posterior nares is avoided. An incision 2 cm. long is made transversely in the frænum of the upper lip, and by blunt dissection the lower margin of the nasal septum is exposed. The mucous membrane is then dissected back from the septum on both sides, and retractors are inserted allowing of the removal of a strip of septum including most of the vomer, the lower edge of the median plate of the ethmoid, and a small strip of cartilage. Dilating forceps are then introduced between the retractors (so as to flatten the turbinates), and a bivalve speculum is inserted in place of the retractors. With the aid of a good hand-light the attachment of the septum to the sphenoid is exposed, and the anterior and lower walls of the

sinuses are chipped away with special rongeurs. The lining mucous membrane of the sinus is then removed and the floor of the exposed sella turcica taken away (*Figs.* 77–80). No drainage is carried out. "Every step must be absolutely under the operator's direct vision."

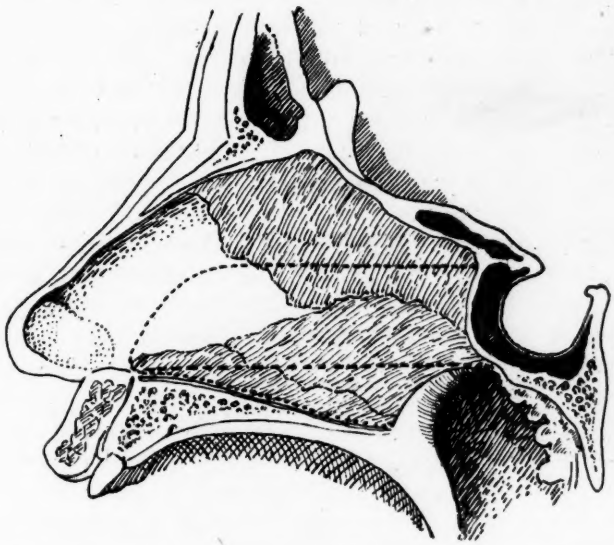

FIG. 79.—Cushing's operation. Stage 3. Dotted lines indicate part of septum removed.

The differences between Cushing's technique and that of Hirsch are as follows: Hirsch operates under local anæsthesia. A preliminary removal of the middle turbinates is customary some days before the main operation, so that dilatation of the submucous passage by special plugs is unnecessary. The initial incision is made through the mucous membrane of the septum to one or other side. Hirsch lays stress upon precise arrangements being made for the operation, to ensure an undisturbed procedure. A sterilizer is kept handy and the instruments are frequently re-sterilized during the operation.

The fronto-orbital method of Frazier (which itself is a modification of MacArthur's technique) is performed by that operator in the following manner: As a preliminary, the frontal sinuses are transilluminated in order to observe their relation to the supra-orbital margin. Under general anæsthesia an osteoplastic flap is formed in the frontal region. The line of incision starts at the external angular process, and is continued forward along the supra-orbital ridge through the eyebrow-line till the mid-line at

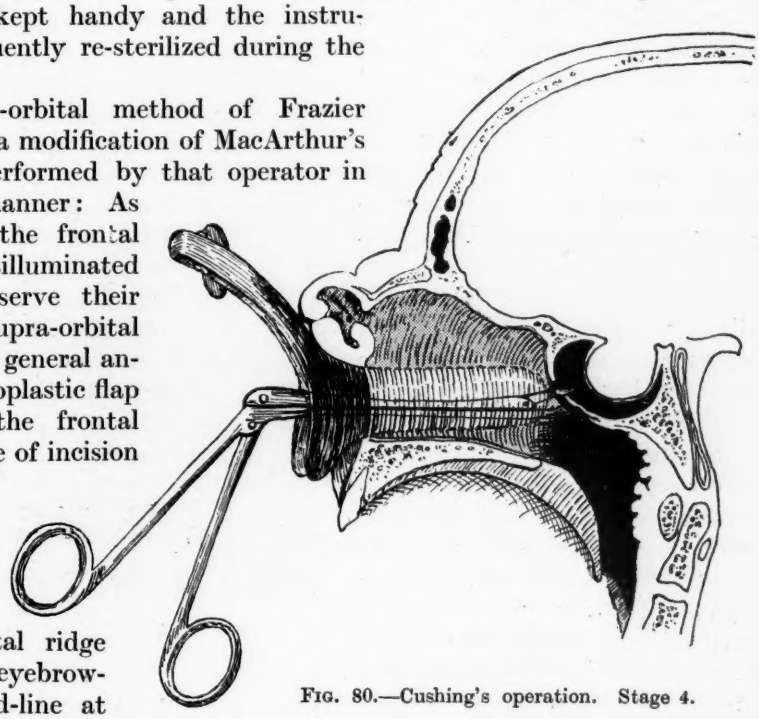

FIG. 80.—Cushing's operation. Stage 4.

the root of the nose is reached; then it ascends vertically till well within the scalp hair line, finally turning horizontally outwards and returning to the temporal region on a level with the beginning of the incision. The tissues are retracted sufficiently to allow the necessary openings to be made for the reflection of the bone-flap which is turned outwards. The outer portion of the supra-orbital ridge is removed in wedge-shaped fashion, so that the fragment can be replaced without mechanical fixation. The periosteum is freed from the roof of the orbit, and the thin roof itself removed with rongeurs as far back as the optic foramen. If necessary, a small opening may be made on the dura in order to allow cerebrospinal fluid to escape and thus permit of greater displacement of the frontal lobe. With flat retractors the orbital contents are now displaced downwards and outwards, and the frontal lobe, still covered by the dura, is elevated until a view is obtained of the optic nerve as it passes from the optic foramen towards the sella. The dura is then incised in a horizontal direction, about a centimetre above the base of the skull, for a distance wide enough to admit the blade of a retractor and to expose the contents of the sella (*Figs.* 81–83).

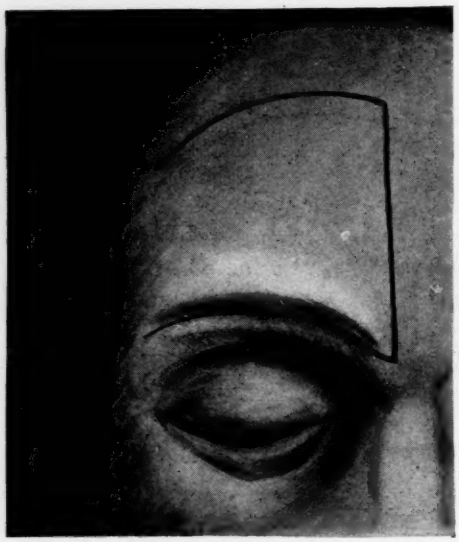

FIG. 81.—Frazier's operation. Stage 1. (*After Frazier.*)

This operation has been slightly modified by Elsberg, who makes the base of the flap in the mid-line, thus avoiding the visible vertical scar. Elsberg[32] also removes the orbital margin in one piece with the bone-flap.

No useful purpose would be served by describing in detail the more rarely performed operations. We may state, however, that König's operation consists in splitting the soft palate, removing the posterior part of the hard palate, and so obtaining a direct view

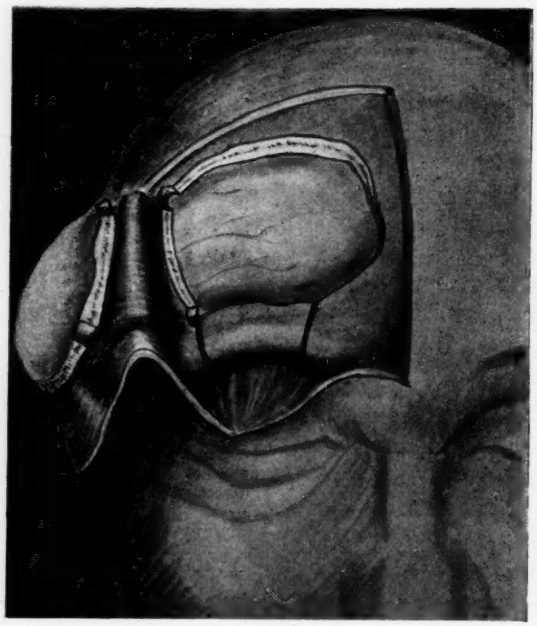

FIG. 82.—Frazier's operation. Stage 2.

of the sphenoid through the mouth. The sphenoidal sinus and sella turcica are then opened by the chisel.

Chiari entered the nose by a paranasal incision, and after exenterating the ethmoidal cells and retracting the eyeball outwards, reached the sphenoid cells (*Fig.* 84). Kahler has modified this technique so as to keep nearer the orbit; this, to a certain extent, diminishes risk of infection from the nose, but the approach to the sella is somewhat oblique and lateral.

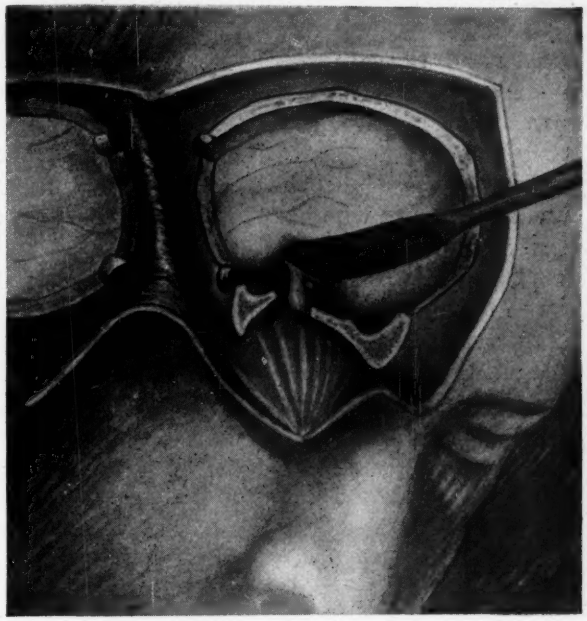

FIG. 83.—Frazier's operation. Stage 3.

Results of Operations.—A successful operation does not always mean permanent cure, and in the case of pituitary tumours, which usually cannot and ought not to be fully extirpated, it is to be expected that some recurrence of symptoms will ultimately occur. Before the surgeon embarks on a pituitary operation, he should be able to give the patient some idea as to the extent and duration of the improvement of symptoms which can be expected.

In the majority of cases the immediate benefit is great, especially as regards the improvement in sight when the chiasma has been pressed upon. But it is more difficult to say how long the improvement lasts, inasmuch as most of the results of the later and more satisfactory operations have been published within a comparatively short time of their performance.

FIG. 84.—The Chiari-Kahler operation. (*After von Szily.*)

Of the 23 successful cases which Hirsch operated on by his method, 5 were only temporarily benefited for periods varying from two to six months, whilst 15 showed improvement as to vision, memory, intelligence, etc., for periods up to two years; 3 of his cases showed no improvement.

The late results of Cushing's septal-sphenoidal operations have not, so far

as I know, yet been published; in his book one gathers that recurrence of symptoms sometimes takes place within a few months, though undoubtedly we shall find many more lasting cures. The results from sellar decompression were frequently so fleeting that a partial extirpation had to be undertaken later.

Von Eiselsberg records several cases which maintained general improvement for over two years.

No late results of the fronto-orbital method have been published, so my own limited experience may be of interest. One of my cases (*Case* 1), who had a large endothelioma in the pituitary region, showed improvement in general pressure symptoms for eighteen months, but lately pains have restarted. Another case, in whom a pituitary cyst was evacuated, maintained very marked improvement in vision and general pressure symptoms for over a twelvemonth; but I have heard lately that he has been treated at a Glasgow hospital, presumably for some recurrence of symptoms. In reference to the transfrontal route, Professor Cushing writes, "If a cyst is exposed and evacuated it has always tended to refill, with return of the pre-existing visual defect." I think it should be possible to prevent this by removing a portion of the cyst wall in future cases.

Whether the benefit accruing from the fronto-orbital operation will prove to be greater or more lasting than that from the trans-sphenoidal method is yet impossible to say; but since the general intracranial pressure is more easily relieved, and growth can be removed from the more immediate neighbourhood of the chiasma, by the fronto-orbital method, it is likely that this operation may have the advantage. Experience will prove.

The suggestion thrown out by Hochenegg that a combined nasal and intracranial method might be better than either route singly has, so far as I am aware, never been put to the proof, but it is possible that developments in this direction may yet take place.

Mortality Statistics.—In considering the mortality statistics of the various routes of approach, there are several sources of fallacy. The extent of intracranial growth and amount of increase in intracranial pressure prior to operation have an important bearing on prognosis, and it is not fair to compare results of cases with marked general pressure symptoms with those where the growth is confined to the fossa. We cannot judge the value of the methods by studying isolated cases done by different operators, who are more prone to register successes than failures. Therefore, so far as is possible, the following statistics deal with series of cases performed by various operators.

The most important available figures can be tabulated as shown on opposite page.

It should be added that Cushing's eight temporal explorations did not promise to give him a satisfactory approach without undue retraction of the temporal lobe, so with the exception of two cases the operations were not completed, and should hardly be included in the statistics. Hirsch excluded from his figures one case in which a fatal result occurred after operation, where the post-mortem showed the presence of a local hydrocephalus and not a pituitary tumour.

Method	Operator	Number of Operations		Deaths		Mortality per cent
Schloffer's nasal route..	Von Eiselsberg	16		4		25
Submucous septal ..	Hirsch ..	26	132	4	12	9
	Cushing ..	106		8		
Temporal	Horsley ..	10	18	2	2	11
	Cushing ..	8		0		
Fronto-orbital ..	Frazier ..	4	23	0	2	8·6
	Cushing ..	16		1		
	Sargent[33] ..	3		1		
Paranasal	Kahler ..	7	9	0	0	0
	Chiari ..	2		0		
Palatal	Preysing ..	6		4		66

The author's three successful cases by the fronto-orbital route are not included in this table.

Consideration of the Merits of the Various Methods.—The nasal route of Schloffer, with its various modifications (except the submucous) is fundamentally unsound. The sella is approached crudely through the nasal cavities, which are usually teeming with microbes and often harbour foci of suppuration in the adjacent sinuses; open raw surfaces are left by the removal of the turbinates and septum which must take a long time to heal and which are a constant danger of infection. Added to this, considerable deformity of the external nose may follow. Moreover, von Eiselsberg, the great advocate of this method, has to confess that a horrible odour emanates from the nose of those cases that recover. (The modifications of West and Citelli, which traverse the nasal passage but only remove the posterior part of the septum, are open to similar objections, and the added one that the avenue of approach is very much more restricted.) This *a priori* reasoning is borne out by operative facts, as the table shows.

Similar objections lie against the palatal method, which traverses the septic postnasal space. Here there is also likely to be some danger of aspiration pneumonia. At any rate, Preysing's series of six cases is sufficient for us to condemn it.

The method of approaching the sphenoidal sinuses through the ethmoid by an external incision (Chiari-Kahler) has against it the same theoretical objections that stand against Schloffer's operation; and though Kahler has had some success, it is too early yet to say much in favour of it. It is certainly no better than the median submucous method.

The temporal method has only been found practicable by one operator, who has a considerable mortality, and the records of those cases which have been published do not encourage us to hope much from this route.

If one is to approach the pituitary fossa through the sphenoidal sinuses, it is clear that the only promising, one could almost say justifiable, method is that of Hirsch and Cushing. Especially in the hands of the latter, who adopts the sublabial incision, this operation has been attended by very little risk of meningitis; in a personal communication received in January this year,

Professor Cushing writes that in the previous eighteen months he had performed 32 sublabial operations with only 1 death—a truly remarkable achievement.

There are grave drawbacks to the adoption of local anæsthesia for such a serious operation as the removal of part of a pituitary tumour. In the first place, it is impossible to guarantee that the patient shall not feel pain during manipulation of the dura or contents of the sella turcica. Thus, in *Case* 8 of Hirsch's series, the operator " inserted a sharp spoon six or eight times, whereat the patient several times gave evidence of severe pain " ; and in *Case* 19, " immediately after the contents of the cyst had been evacuated, the patient complained of severe pains in the head." Again, there is danger that sudden pain might cause a patient involuntarily to hinder the operation. For example, in describing *Case* 24, Hirsch writes : " On account of the patient's demented condition the operation proved difficult. The patient touched the instruments with his hands, wiped away blood, etc. ; in spite of everything, however, the operation was carried out aseptically." The fact that the patient died three weeks later from suppurative basal meningitis does not help the operator's argument, though clearly no causal connection can be proved. A third danger consequent on utilizing local anæsthesia is that sudden unconsciousness may supervene and stop the operation. Thus, in the account of a case recorded by Stein[38] carried out by Hirsch's method, we read the following : " Touching the dura caused great pain, and in an effort to orient myself as well as to mop the field for inspection . . . I resorted to the use of a cotton-wrapped probe. While doing this shortly before finishing completely the decompression, the probe entered the brain on the left side, immediately causing a collapse of the patient, with every sign of hæmorrhage into the brain, even to unconsciousness, paralysis, and retarded breathing." In view of these drawbacks, added to the extra restraint which is likely to be felt whilst the patient is conscious, we consider that local anæsthesia is unjustifiable in the majority of operations upon the pituitary fossa.

Hirsch in his first 26 operations lost only 1 case from meningitis, but two others recovered after severe septic trouble at the base of the brain ; whilst in Cushing's earlier series meningitis occurred 4 times with 3 fatal results. The experience of Cushing and of Sargent appears to indicate that there is greater risk of meningitis in operations undertaken by the submucous trans-sphenoidal method when the diagnosis has been mistaken or when the tumour has arisen above the sella. Nevertheless there must always be a slight danger of meningitis, even with the submucous operation, inasmuch as the sphenoidal ostia open into the nose. The submucous method is one which requires special skill in working in such a confined space. It has several special difficulties dependent on the variations in size and shape and relations of the sphenoidal sinuses, and even when the sella is opened, the surgeon is working more or less in the dark, for he cannot see what relationship his inserted spoon bears to the third ventricle ; if the ventricle is opened, a cerebro-spinal rhinorrhœa fraught with great danger of infection may ensue. We are well aware that pathological changes may favour the surgeon ; but though any existing pituitary bulge into the sphenoidal sinus is likely to be increased by the advent of a neoplasm, still there are many cases in which no such bulge

exists, and on several occasions operators (Cushing, Halstead, etc.), have had to stop the operation and insert a metal clip for radiographic orientation purposes.

If the nasal method be adopted, some external or independent guide as to the direction in which the nose must be traversed may be a help. Nassetti[36] states that the deepest point of the sella is situated 1·7 to 2 cm. above the horizontal line of Ihering* and 2 to 3 cm. in front of the binauricular line. For purposes of orientation Schepelmann took a straight piece of wood, marked it by the aid of the radiogram at a point which indicated the distance from the nasal spine to the sella, and (after sterilizing it) placed it in the nose, with the marked part on the nasal spine, and the length parallel to a line—previously marked with silver nitrate on the exterior of the face and scalp—drawn from the left middle incisor through the middle of a horizontal line extending from the most lateral point of the bony orbit to the upper anterior part of the external ear; when the marked piece of wood is placed in the nose parallel to this line, with the mark on the nasal spine, the point corresponds to the sellar floor. Graham[37] has also described a line for guidance: "The position of the pituitary fossa was found by taking a line which commences at the junction of the ala nasi and upper lip, and runs upwards and backwards towards the parietal eminence of the same side; this line will be found to pass immediately beneath the lower and outer margin of the orbit." In most cases, however, a previous careful measurement of the radiogram, and frequent estimation of the depth reached in the nasal fossa, will suffice to guide the operator.

In children who have undeveloped sinuses of the presphenoidal type, it seems to be an especially unwise proceeding to adopt the nasal method. If, however, the submucous nasal operation is adopted, it would be a wise plan not only to study the *x*-ray plate carefully, but also to make a preliminary sounding of the sphenoidal sinuses, as suggested by Blumenthal.[35] If the trans-sphenoidal crest is shown by the *x* rays, it should provide an absolute guide to the pituitary fossa after the sphenoidal sinus is opened.

In favour of the fronto-orbital method are the facts that it provides an aseptic route, allows each step of the operation to be performed by the aid of sight, and does not necessitate so much dislocation of the brain as the temporal method. It is true that some œdema of the eyelid occurs after the operation, and that on occasion the eyeball may be left for a time not quite on the same level as the opposite one. This latter drawback should be avoided by care at the time of the operation, though since one is usually dealing with an amaurotic eye, the defect is chiefly cosmetic. The frontal sinus is sometimes in the way, but by previous *x*-ray or trans-illumination one can estimate its size and avoid it at the time of operation, and if it is opened it may be temporarily plugged.

An additional fact in favour of this method is that the primary enlargement of hypophyseal tumours is towards the brain (*Figs.* 85–87); the enlarged gland thus presents an easier object for attack by the frontal route. By far the most common indication for operation in pituitary tumours is oncoming

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* Ihering's line is the same as Reid's line.

blindness (*Fig.* 88). (In the last 58 cases which Professor Cushing has treated since the publication of his Weir-Mitchell Lecture in June, 1914, all have shown visual disturbances from pressure on the optic chiasma.) It would appear more rational, other things being equal, to relieve pressure on the chiasma by removing a part of the tumour which is close to, rather than a portion remote from, that structure.

An objection which has been brought by Coffin against the fronto-orbital method is that the relief afforded is less lasting than by other methods. We should imagine that this could only be possible in the case of cysts, which

FIGS. 85, 86, 87.—Cases respectively of Hirsch's, Cushing's, and Lecène's, showing upward growth of tumour, *not suspected before operation.*

might fill up again. Indeed, as already mentioned above, the weight of Professor Cushing's authority is added to this view. The objection would be more valid if it could be levied against the frontal approach only. Such is not the case, for in two out of the three cases of cysts of which full details are published by Hirsch, the fluid re-collected, and required in the one case two after-operations and four punctures, and in the other case three punctures and two after-operations. On *a priori* grounds one would expect the general relief of pressure by the cranial route to allow a much greater accumulation of fluid before pressure symptoms ensued.

Of course, if the growth is primarily suprasellar, most, if not all, operators

would select the intracranial method. It is often difficult to say whether the growth is supra- or intrasellar.

It is true those cases of acromegaly in which the gland, though enlarged, is confined to the sella, might reasonably be treated by the nasal route; but it is a little doubtful whether one should adopt an operation with a 7 or 8 per cent mortality for the ordinary symptoms of acromegaly.

To sum up, we may say that there are two operations which have proved fairly satisfactory for approaching the pituitary fossa, the Hirsch-Cushing submucous nasal method, and the fronto-orbital method of Frazier. Though it is not possible yet to decide finally between these, the opinion can be expressed that the fronto-orbital route is more suitable in the great majority of cases. In the three cases which the speaker has operated on, this method has been adopted with success. Now that the mortality of the operation has diminished, surgeons can more readily urge that patients with oncoming blindness, due to pressure on the chiasma, should be treated by operation more early than is now the case.

FIG. 88.—Specimen from a case of acromegaly, the patient being blind for years before death. (*R.C.S. Museum.*)

I desire to thank Professor Arthur Keith and Professor J. E. S. Frazer for their kind advice and help in the anatomical research embodied here, and also to acknowledge the courtesy of the authorities at the Zoological Gardens and the Natural History Section of the British Museum, who kindly gave me special facilities.

All the illustrations were either photographed or drawn from original specimens, or copied with modifications from illustrations elsewhere, by Mr. R. Clyne, to whom I cannot sufficiently express my gratitude for the skill and care which he has bestowed on them.

PERSONAL CASES.

Case 1.—E. S., female, age 44, married, was admitted to St. Mary's Hospital under the care of Dr. Wilfred Harris, April 28, 1914, complaining of headache, drowsiness, and failing vision.

HISTORY.—The symptoms had started four years previously, with bilateral frontal headache, pain at the back of the eyes and nose, and occasional vomiting. Loss of memory and dulling of the emotions gradually developed, and after two years drowsiness was noted. The visual symptoms started two years ago, almost suddenly, as a dimness whilst reading. Both eyes were affected, but during the six

months prior to admission the right eye had become much worse. Diplopia had never been noticed. Had become much fatter lately.

On Admission.—Patient was stout, had marked diminution of visual fields, but was fairly intelligent. Pupils large, L>R, react to light and to accommodation. Eye movements normal, no diplopia, no nystagmus. Slight temporal atrophy of the optic discs. Reflexes, sensation, and motor system normal. Visual acuity less than J 20 ; central scotomata. Thyroid normal. Wassermann reaction of blood negative. Sugar tolerance increased ; no glycosuria after 200 grams glucose, but considerable after 250 grams. Catamenia normal until three months ago ; since then diminished.

Treatment by thyroid extract (gr. iij bis die) and by pituitary extract (anter. lobe extr. ℥xx alternate days).

In spite of treatment the vision became worse, so that the right eye was nearly blind on July 28. Hallucinations were at this time a marked feature, and temporary attacks of mental aberration developed.

Operation, Aug. 31, 1914.—The patient was transferred to my care. Following the incision recommended by Frazier, a skin flap was outlined over the right frontal region with the base towards the temporal fossa. A rectangular piece of the right frontal bone was removed by the use of a trephine and Gigli's saw. The supra-orbital margin was removed separately, and the roof of the orbit taken away piecemeal. The eyeball was depressed and the dura mater elevated so as to expose the median region in front of the pituitary fossa. The dura was here very thin, and easily tore, exposing a red papillary granular-looking mass. Some of this mass, which was evidently a new growth, was removed, and it was considered inadvisable to proceed further. The supra-orbital ridge was replaced, but the piece of frontal bone was not put back again. No drainage was used. After the operation the conjunctiva and lids of the right eye were for some time swollen and œdematous.

The sight did not improve, and the mental aberration noticed before operation became more marked. For a short time the patient had to be placed under restraint. The headaches were cured by the operation.

Feb. 7, 1916.—The sight has not improved. The mental condition is quite good. She has occasional fainting fits.

The microscopical examination of the tissue removed from the growth was reported by Dr. Spilsbury to show the presence of an endothelioma.

Case 2.—John W., age 21, was admitted to St. Mary's Hospital under the care of Dr. Harris, on Jan. 5, 1915, complaining of impaired vision, severe headaches, and attacks of giddiness.

History.—Patient had meningitis when two years old. Has had fits from time to time. Ten years ago he had an operation for stone in the bladder. The present illness started ten months before admission, with failing eyesight, and though he has been subject to headaches for years, only recently had they caused him great inconvenience.

On Admission.—Height 3 ft. 8 in., weight 49 lb. Said to have stopped growing when six years old. Sings in a fine treble voice, and dances and sings well as a music-hall artiste.

Occipito-glabellar measurement, 21 in. Head distinctly hydrocephalic. Body and limbs are well formed, but the general appearance is that of a child of six years. No development of hair except on the scalp. Testes not fully descended. Skiagrams show unossified epiphyses and a large sella turcica. Five ounces of glucose produced nausea but no glycosuria. The left eye is blind save for perception of a strong light in the temporal field. In the right eye, he counts fingers only in the upper nasal field. Fixation is excentric. The right pupil reacts directly to light, the left consensually only. The optic discs are both atrophic, with blurred edges. Lumbar puncture showed normal cerebrospinal fluid, and the removal of 25 c.c. improved vision decidedly. When dancing on the stage lately has had attacks of giddiness. Suffers from severe headaches.

Treatment at first by pituitary extract, gr. ij bis die.

Operation.—As no improvement occurred, operation was undertaken in Feb., 1915. Frazier's operation was carried out on the left side. Trouble was experienced

from a large frontal diploic vein, which stopped bleeding after plugging with wax. As the dura was being stripped up from the anterior margin of the pituitary fossa, a sudden gush of fluid took place owing to the giving way of the dura. The fluid, amounting to about half an ounce, was brownish-yellow in colour and was full of cholesterin crystals. The wall of the cyst was not removed, and no drainage was instituted. The frontal bone-flap was replaced, and the skin sutured.

After the operation there was no shock. The headaches ceased at once and the patient felt better in every way. The vision of the right eye improved rapidly. Within a few weeks he could tell the time by a clock high up on the wall of the opposite side of the ward, and could read large print fairly readily. He was able to go back to his work as a dancer in a few months, but lately has had to give it up again.

Case 3.—William P., age 48, was admitted to St. Mary's Hospital, under care of Dr. Harris, on Sept. 10, 1914.

History.—Began to find difficulty in reading four years before coming under observation. At one time he had visual hallucinations. His vision has gradually decreased, and he has had shooting pains in both temples. He had venereal disease twenty years ago.

On Admission.—He was almost blind. Vision of right eye—perception and projection of light only ; of left eye—perceives hand about eight inches away. Cerebration and speech good. Slight nystagmus. Atrophy of optic discs. Wassermann reaction positive. Sella turcica shown by radiography to be considerably enlarged. It was thought by Dr. Harris that the symptoms might be caused by a pituitary tumour, and that operation might relieve them.

Operation, Oct. 28.—The fronto-orbital method on the right side was adopted. A quadrilateral piece of the frontal bone was removed and put aside, and the supra-orbital margin and orbital roof were removed. The dura was not tense and it was easy to elevate the frontal lobe with its dura. By depressing the eyeball it was possible to approach the pituitary fossa without difficulty. When the dura at the anterior margin of the fossa was penetrated, a large amount of cerebrospinal fluid escaped, and a splendid view of the floor of the fossa was obtained and demonstrated to those in the theatre. There was no tumour, and no pituitary substance was seen. The parts were then replaced and the skin sewn up.

Oct. 30.—Patient feels well, but has some pain in the right eye. There is some ecchymosis of the right orbital region, and protrusion of the eyeball. The eye symptoms soon subsided.

February, 1916. The sight is no better.

This case was most likely one of chronic syphilitic meningitis and optic atrophy. The enlargement of the sella is secondary to this condition. Though the patient expressed himself as better after the operation, no improvement of value occurred.

This patient died on May 10, 1916. No post-mortem was obtained.

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NOTE ON TUNNELS AND LARGE CAVITIES IN BONE.

By Lieut. NORMAN F. LOCK, R.A.M.C. (T.C.)

During the six months since the Queen Alexandra Military Hospital Extension was opened at Millbank, our attention has been particularly drawn to cases of chronic suppuration in bone. Among the first fifty patients admitted, there were no less than nine who had been wounded more than six months previously, all of whom had discharging sinuses in their limbs. They had been in various hospitals and convalescent homes, and all had had their sinuses scraped on several occasions.

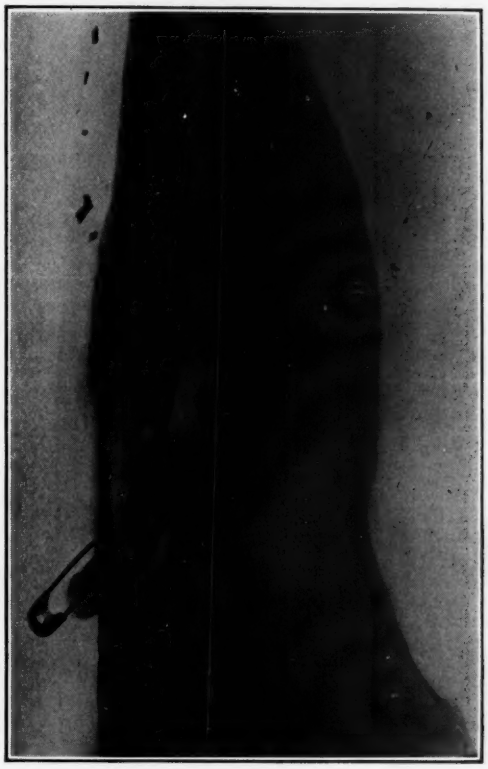

Fig. 89.—*Case* 1, before operation. The probe passes right through the bone.

Skiagrams were taken of these cases, and it was immediately found that they fell into two groups: In four instances foreign bodies—pieces of shrapnel or bullets, etc.—were found, generally on the side of the limb remote from the opening of the sinus, which perhaps explains why they had been missed; the remaining five cases had been compound fractures of the long bones in which the bone had been perforated by the bullet. The skiagrams showed that the bones had united on each side of a central cavity or tunnel, as is well shown in the illustrations. On investigating the history of these cases, it was found that a tube had been passed along the track of the bullet shortly after the receipt of the wound, and kept in for some considerable time for drainage. The sinus was generally situated on the upper aspect of the limb as the patient was lying in bed, while the more dependent scar had healed over. At the time these patients came under our notice, it was impossible to tell from an examination of their wounds which had been the entrance and which the exit wound. Several more cases of a similar nature have since come under our care.

Typical histories are as follows :—

Case 1.—Cpl. W. : Bullet wound of left femur five inches from lower end ; compound fracture. Wounded Sept. 9, 1914. Wound freely drained, a tube being passed right through the limb. Bone plated at St. Nazaire, Sept. 24. In October bullet was removed. Wound continued to discharge freely. In November the plate was removed at Millbank. The fracture now united. Wound was scraped, disinfected, and drained in April, May, August, and November, 1915, and on Jan. 13, 1916, when a tunnel traversing obliquely from before backwards through the lower end of femur was found (*Figs.* 89, 90).

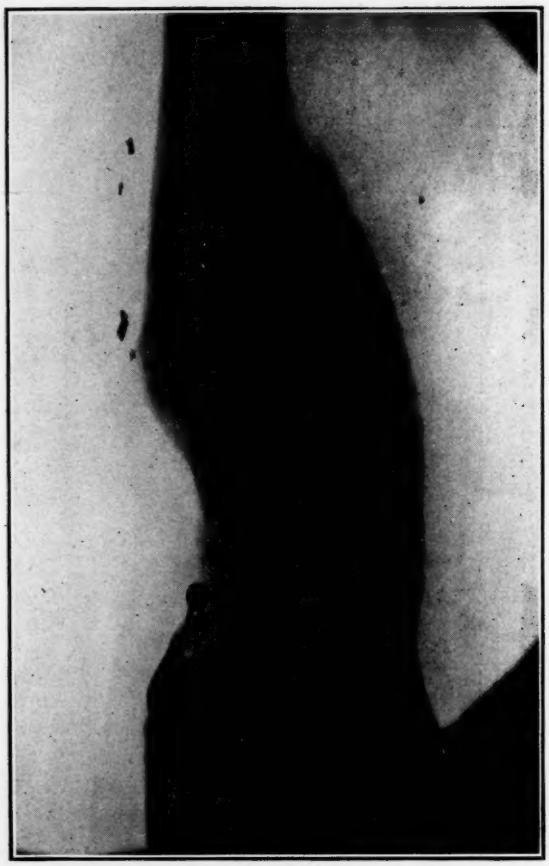

FIG. 90.—*Case* 1, after operation. The whole of the outer wall of the tunnel has been removed, and the drainage tube inserted from behind. This case healed up completely two months after the operation described in the text.

Case 2.—Pte. C. : Bullet wound of right arm, causing compound fracture of humerus in lower third. Wounded at Neuve Chapelle on March 10, 1915. Complicated by musculospiral nerve injury and wrist-drop. Next day wound was cleaned up and freely drained, a tube being passed right through the humerus from side to side. Bone joined in about eight weeks, but wound continued to discharge. Sinus scraped and cleaned in May and July, 1915. Admitted to Millbank Nov. 11, 1915. *X* rays show a tunnel through the lower end of the humerus from side to side (*Figs.* 91, 92). On Nov. 7 the sinus was scraped and drained, with counter-incision through lower scar, which had healed.

The histories of the other cases are precisely similar : many attempts to obtain healing by routine methods of curetting and disinfection of the sinuses, which nearly heal ; transference of the patient to a convalescent home, where the sinus breaks down ; return to the same or another hospital, and the process is repeated.

Of eight cases treated in this way during the last three months, only one has healed. In this case there was a tunnel passing from side to side through the middle of the shaft of the humerus ; several small sequestra were removed from the cavity, and the sinus healed up one month later (see *Fig.* 93) ; the patient had had the sinus scraped out and drained on no less than six occasions before the skiagram was taken. The remaining cases invariably improved to a certain extent, and then came to a standstill, a small sinus persisting, from which a little seropurulent material continued to ooze.

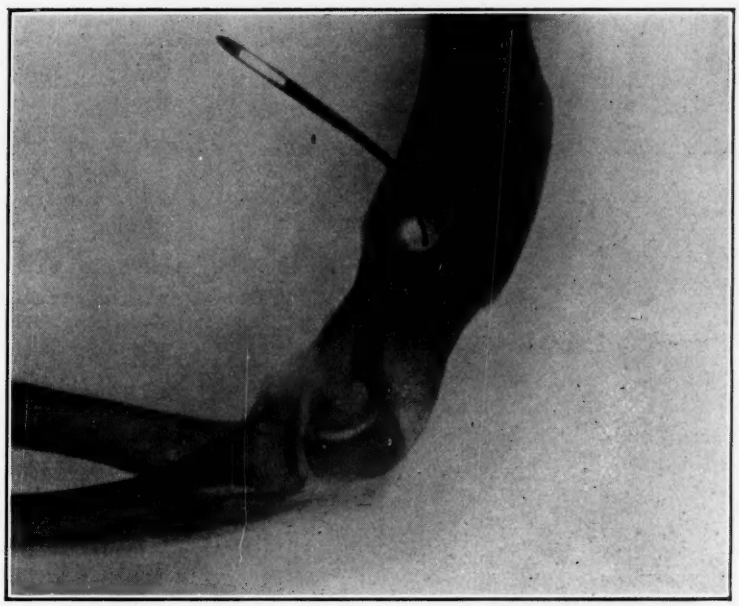

FIG. 91.—*Case* 2, before operation. The probe passes right through the humerus.

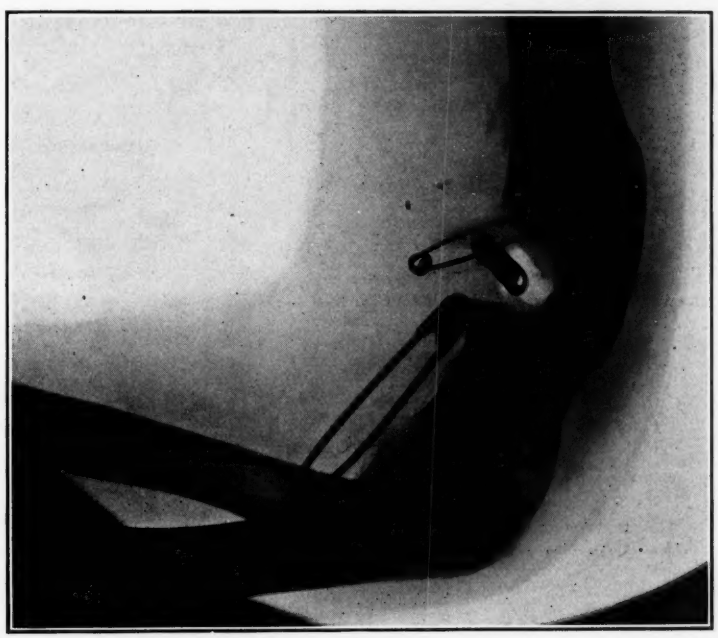

FIG. 92.—*Case* 2, after operation. The anterior wall of the tunnel has been removed subperiosteally. This case had healed completely three months after the operation described and shown in the above figure.

The reason why these cases fail to heal is probably mainly anatomical. There is present in the walls of the cavity a slight chronic infection, with which the tissues are unable to deal in the ordinary way. This cavity cannot be obliterated by granulations, because the walls are rigid and will not collapse; when such granulations grow up beyond a certain point, the contracting scar tissue underneath, being unable to draw the surfaces together, strangulates the blood-supply to the more superficial granulations. (See also note on page 153.)

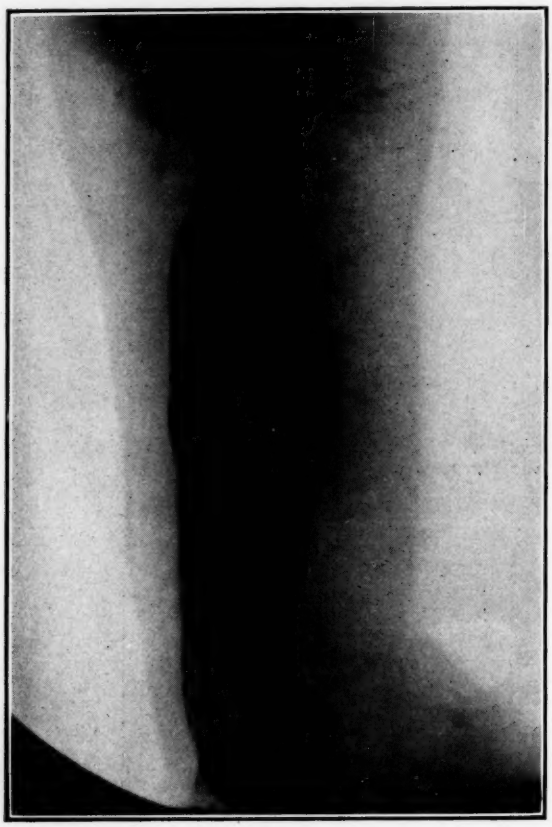

FIG. 93.—Showing a tunnel through the humerus, with several small pieces of bone in its lumen. This case returned to us from a convalescent home three and a half months later, the sinus having broken down a fortnight after the patient had been sent there. A complete subperiosteal resection of the anterior wall of the tunnel was performed, and the wound has now nearly healed again, one month since the operation. The result of this operation is shown in *Fig.* 94.

There is not much evidence of osteosclerosis being present, as during operation the bones are not found to be unduly dense. The signs are rather those of a subacute or chronic periostitis, and it seems probable that in some cases flakes or superficial plaques of bone continue to be thrown off into the tunnel (see *Figs.* 93 and 95, where each sinus had been scraped out several times before the skiagrams were taken). We have not, however, seen these sequestra develop in any case we have had under our care.

There is very little evidence of osteomyelitis, as the medullary cavities have been shut off by callus, which has become organized into quite definite layers of bone; this can be seen in any of the skiagrams, and is confirmed by the findings at operation, the medullary cavity being plugged with smooth firm bone. It is in this respect that these cases differ from those with cavities where the bullet has penetrated, but not fractured, the bone; in the latter, little or no callus has been thrown out, and the medulla is shut off from the cavity by granulation tissue only (see *Fig.* 99).

As some of these tunnel cases are further complicated by injury to nerves, especially in the case of the humerus, where the musculospiral nerve is so apt to be involved, it is all the more desirable to find some means of shortening the period of healing; as, of course, no attempt at repair of the damaged nerve can be made till healing has occurred.

On referring to Binnie's *Operative Surgery*, we find no less than ten more or less different methods described for obtaining the closure of large cavities in bone, but all depending in some measure on adequate sterilization of the cavity as a preliminary measure. It is just this preliminary sterilization, however, that is the most difficult part. Professor Burghard writes in his *System of Surgery*: "The closure of a cavity in bone is practically impossible as long as sepsis persists; and obviously the first step in the treatment is to secure asepsis. Otherwise the cavity will discharge indefinitely. Sometimes it is fairly easy to make a cavity of this kind aseptic, but sometimes it is impossible." The methods he advises are, firstly, free incisions and adequate drainage, disinfection with hydrogen peroxide and 1–20 carbolic left in the cavity for ten minutes, and occasional scraping and the application of pure carbolic to the walls of the cavity, the latter under local anæsthesia. When no further improvement is obtained, he operates as follows: The surrounding parts are carefully purified, the sinus being plugged with pure carbolic; the sinus is then completely excised, and a quarter of an inch of bone is removed all round by chiselling and gouging. Having thus obtained an aseptic cavity, he closes it either by Schede's aseptic blood-clot method, the soft parts being mobilized and sutured over the aseptic blood-clot which fills the cavity, or by filling it with Mosetig-Moorhof's paste or Beck's bismuth paste, and suturing the skin over this. If a truly aseptic cavity can be obtained, fresh human bone chips might be used, as in Macewen's method of bone grafting. We have had no success with the bismuth paste method, being unable to make the cavity aseptic first. It has been impossible to adopt this technique in its entirety, as the removal of so much bone would have made an opening into the medullary cavity; further, the use of pure carbolic is contra-indicated owing to the proximity of important nerves and vessels.

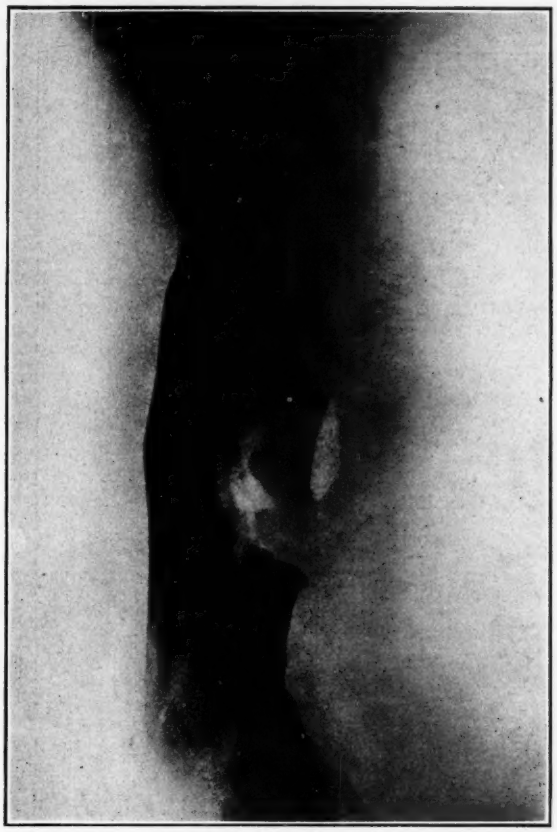

FIG. 94.—Showing result of operation.

The operation we have devised to overcome these difficulties is sufficiently simple; yet it did not occur to us till we had watched these cases for three months. It consists in the complete removal of one wall of the tunnel subperiosteally, so as to allow the soft parts to fall down on to and obliterate the lumen of the tunnel, after the manner of Estlander's operation for mobilizing the chest wall.

With regard to the time at which this operation may be performed, it would probably be wise to wait until five or six months have elapsed since the injury, so that the fragments may be firmly consolidated. Also, the risk of setting up an acute osteomyelitis will be much less after an interval has elapsed long enough for the medullary canal to have been firmly sealed by new bone developed from the internal callus.

FIG. 95.—Perforation of radius and ulna by a bullet, with several small loose pieces of bone. In this case and in the one shown in *Fig.* 93 the tunnels had been scraped out several times.

The procedure at the operation is as follows: The sinus is first scraped, and cleaned out with peroxide of hydrogen. The skin is then incised at each end of the tunnel in a direction at right angles to its length and in the long axis of the limb. This incision is now carried down to the bone on that side of the tunnel which it has been decided to remove, taking care not to injure any important structures in the neighbourhood. The periosteum is raised up with the skin and intervening soft parts from that wall of the tunnel which is to be removed. The bone is then sawn through so as to remove a wedge-shaped piece, the broad end of the wedge being away from the tunnel: we find a Gigli saw an efficient instrument for this purpose. The sharp edges of the groove so made are smoothed off with a chisel, so that they shelve gently down to the cavity of the tunnel. This can generally be effected without opening up the medullary cavity of the bone at all. A drainage tube is inserted, going from the most dependent opening to the bone. Finally, the limb is bandaged firmly, so as to press the soft parts down into the tunnel and obliterate its lumen as far as possible.

At first there is some increase of the discharge, but this soon diminishes,

and the sinus will heal. The radiographic appearances of *Cases* 1 and 2 after operation are well shown in *Figs.* 90 and 92.

From the nature of these cases, the tunnel will usually be found to pass nearly through the middle of the bone. If the wound were much to one side, the pieces of bone on that side would probably be so shattered at

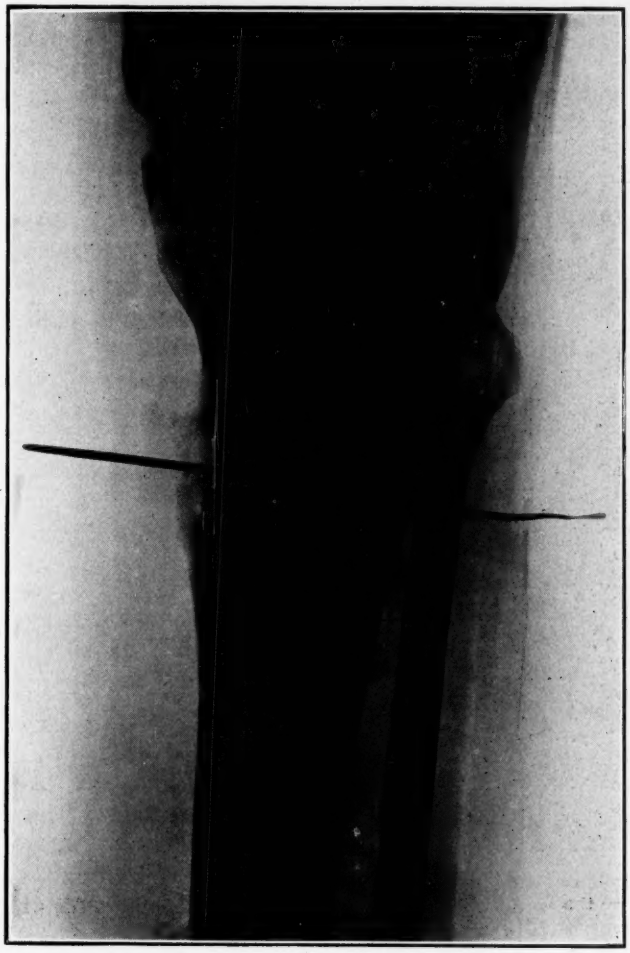

FIG. 96.—Showing tunnel through upper end of right tibia, seen from the front. The probe passes right through the tunnel. The wound has failed to heal after eight months, although scraped and cleaned up on several occasions.

the time of the injury that they would not unite to form a wall of a tunnel, but be discharged as sequestra.

Of course it will be necessary for some time to treat the bone thus weakened with great care, dealing with it in fact as after a sequestrotomy following acute osteomyelitis; but the single limb of the tunnel will soon throw out buttresses of bone and become quite strong.

With regard to large cavities in bone where a bullet has penetrated,

but not perforated, the bone—or where, if perforation occurred in the first instance, one side has joined firmly—it is generally necessary to enlarge the opening so that the walls of the cavity shelve gently down to the base. But after this has been done, it is found that healing is excessively slow. It may, in some cases, be possible to skin-graft such cavities; but even this will leave a very large hole in the bone, covered with skin that is certainly inadequately nourished, as it derives its blood-supply from scar tissue and has no underlying vascular subcutaneous tissue. This difficulty may in some cases be overcome by sliding flaps of skin over the cavity.

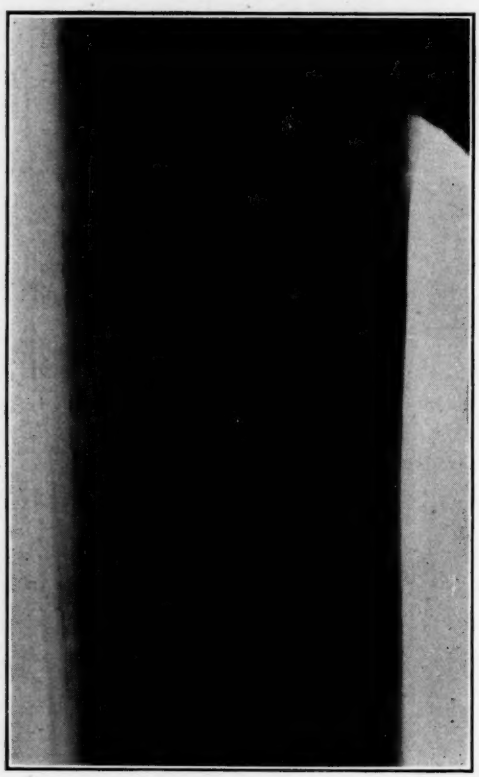

FIG. 97.—The same case as *Fig.* 96, seen from the side.

An alternative method that will be sometimes applicable is to convert the cavity into a tunnel, by making a counter-incision on the opposite side of the limb, and then to remove one wall of the tunnel subperiosteally. The counter-incision will give drainage in a dependent position, and the bridge of tissue may be expected to fall into and obliterate the tunnel. This method is particularly applicable to the tibia if the inner wall of the cavity is on the inner side in front of the calf muscles, as the fibula will become a splint for the time being.

One case, under the care of Major R. Scot Skirving, in which this procedure—slightly modified—was adopted, is illustrated in *Figs.* 99 and 100. In this case there was a large cavity in the anterior aspect of the tibia, from which a shrapnel ball had been extracted: the sides and posterior wall of the tibia were intact, and the bone had not been broken, so that there was practically no callus. This cavity had been scraped out six times in the previous eight months. The whole of the inner wall of the tibia for the length of the cavity, and part of the posterior wall, were chiselled away subperiosteally, and a counter-incision was made just behind the inner border of the bone, through which a drainage tube was inserted down to the bottom of the trough. It was found that the cavity could now be closed in front with sutures, as the soft parts were no longer held apart by the inner wall of the tibia.

One is perhaps not quite so hopeful of success in these cases, as it is impossible to obtain a shelving groove with a smooth surface, such as is obtained after operation on the tunnel cases. Since these bones have

generally not been actually broken across, there is very little callus thrown out, and the medullary canal has not been shut off from the cavity by internal callus. It will, however, have been filled by granulation tissue, and one may expect the bridge of tissue to adhere to this layer and so bring about healing.

It may not be out of place to refer to the local application of oxygen and ozone to these tardily healing sinuses and cavities. This method has been extensively used here and elsewhere by Major Stoker, who has devised the necessary technique. Judging by the cases in which he has carried out this treatment in this hospital, it is certain that the time taken for filling and sound healing is greatly shortened by the daily use of this application.

The manner of the action of the oxygen is easy to understand. We have seen that these cavities fail to heal because the rigidity of the walls prevents them from collapsing, and that the granulations are deprived of an adequate blood supply by the contraction of the subjacent scar tissue. The local application of oxygen enables these granulations to live and proliferate, and so fill up the cavities.

FIG. 98.—Perforating wound of upper end of right femur. The patient was wounded nearly twelve months before the skiagram was taken. The sinus has been scraped on several occasions, but still discharges.

SUMMARY.

1. The presence of tunnels and large cavities in bones as the result of gunshot wounds, as well as from other pathological conditions, is a common cause of persistent sinuses, which continue to discharge practically indefinitely.

2. Tunnels occur in cases where a long bone has been perforated and fractured by a bullet, and where, in treating the septic condition associated with these compound fractures, a drainage tube has been passed right through the middle of the bone, the bone uniting round a central cavity.

3. The delay that takes place in the healing of the sinus is due to the fact that a chronic infection is present with which the tissues are unable to deal, since they are unable to obliterate the tunnel, the rigid walls of which will not collapse, so that the sinus which leads down to the tunnel continues to discharge indefinitely.

FIG. 100.—The cavity shown in *Fig.* 99, with the internal and part of the posterior walls removed.

FIG. 99.—Cavity in tibia caused by shrapnel bullet, without complete fracture of the bone.

The clinical history of this case is as follows: Wounded May 16. Shrapnel bullet lodged in upper end of left tibia, removed next day. Four days later leg freely incised and drained. Bones scraped and drained on six occasions between June and December, 1915. January 25, 1916, operation described on page 152 was done. The wound was soundly healed three months later. Healing was undoubtedly accelerated by the local application of ozone, which Major Stoker was kind enough to undertake.

4. Attempts at sterilization of these cavities and tunnels by scraping and the use of disinfectants are almost uniformly unsuccessful, and therefore the use of such materials as bismuth paste or iodoform paste is doomed to failure.

5. The treatment advised is the subperiosteal resection of one wall of the tunnel—access being gained by longitudinal incisions down to the bone, at right angles to the length of the tunnel—so as to convert the tunnel into a shallow trough or groove; the trough so made is drained through the more dependent incision, and the bridge of soft tissues is pressed down into the bone by firm bandaging.

6. Large cavities in bone are treated in a similar manner, bone being removed subperiosteally so as to convert them into shallow troughs. They are drained by a suitably placed counter-incision, and the bridge of soft tissue is pressed down into the trough so as to obliterate the cavity.

In conclusion, I wish to express my indebtedness to Lieut.-Col. E. M. Pilcher, and to Major R. Scot Skirving, of Sydney, N.S.W., for their advice and for the use of cases; also to Mr. Pooley, radiographer to the Q.A.M.H. Extension, for the great pains he has taken in the preparation of the photographs which accompany this article.

TREATMENT OF TUBERCULOSIS OF THE SPINE.

By F. McG. LOUGHNANE, Leicester.

Tuberculosis of the spine, commonly known as Pott's disease, is one of the most crippling forms of arthrosteal tubercle that surgeons are confronted with. In its early stages, previous to the onset of deformity or changes in the bones as revealed by the *x* rays, it is frequently difficult of diagnosis. Many of the apparently incipient cases resolve themselves into instances of neuromimesis, while it is not rare to see cases in a more advanced stage being treated for disease of the hip-joint or iliac bone, the real seat of the mischief having been overlooked, often for months, until unpleasantly rendered conspicuous by the development of some glaring and serious complication.

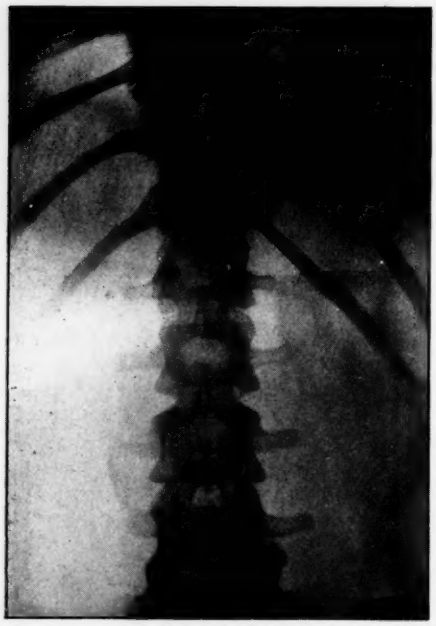

Fig. 101.—Skiagram showing healthy vertebræ in a case of hysteria. The patient had been treated in a double Thomas's hip splint for about twelve months, for tuberculous disease of the lumbar vertebræ. When examined, there was complaint of pain along the spine from occiput to sacrum. No other clinical evidence of disease could be found. Anti-hysterical treatment effected a cure in a very short time.

Tuberculosis of the spine presents difficulties to the consultant as well as to the practitioner. I have seen it confused with hysteria, perinephric abscess, sarcoma of the iliac bone, and morbus coxæ, merely to mention some of the more interesting cases. Too often is proper treatment thereby withheld until indicated by the onset of deformity; or the mimicry of hysteria is so successful as to persuade the patient to accept treatment both cumbersome and protracted. I have seen a patient who was kept recumbent in a double Thomas's hip splint for nine months for suspected disease of the dorsi-lumbar spine, yet complaining of pain and tenderness in every spine from the occiput to the sacrum, and in whom the *x* rays showed perfectly normal vertebræ. Anti-hysterical treatment in this case resulted in cure in a very short time. The neuromimetic spines I have seen have been usually those of young adult, well-nourished women, who often complain of backache, which on careful investigation may be referred to some menstrual or gastric irregularity.

Signs and Symptoms.—Before discussing treatment and the merits of early operative interference, as illustrated by the cases appended, a short account of some of the signs and symptoms is not out of place.

A thorough history in all cases should be taken, though generally it is less important in this than in other diseases. Injury is seldom an antecedent factor; but in one case that figured recently in the coroner's court, acute tuberculosis of the cervical spine was caused by a large sack of flour falling some twenty feet on to a lad's head and neck. The patient was able to cycle home, and felt little the worse for the accident. This was followed in a few weeks by pain, and the formation of an abscess. Curvature of the spine came on suddenly, and the pressure on the cord from this and the abscess caused paraplegia and, later, death. There was no history of tuberculosis in the family, and the patient prior to the injury was said to have been in perfect health.

Sometimes, however, the history itself is misleading, as in a case of Dr. Sawers, of Margate. The patient had been treated elsewhere with electricity and salicylates for over twelve months, for pain in the back said to be due to lumbago. He was a large, heavy, middle-aged man, subject to attacks of rheumatism. On examining the abdomen a left psoas abscess was found, and *x* rays showed disease of the lower lumbar vertebræ. The abscess was evacuated, and the patient kept on his back in bed, when the pains quickly subsided.

Case 6 had been treated for over twelve months for a mass in the left iliac fossa thought to be due to sarcoma of the iliac bone. All this time he was up and walking about, and complained of no symptoms whatsoever. I saw him for the first time a week after he developed angular curvature of the lumbar spine. The mass in the iliac fossa was then definitely fluctuant, and the *x* rays showed collapse and almost complete disappearance of the body of the second lumbar vertebra: it was the first radiograph which had been taken of the spine.

The chief symptom complained of in Pott's disease is pain, which, however, is frequently absent, and when present is seldom pathognomonic, and often elusive and misleading as to its cause. This is true as regards static pain, but that elicited by the carrying out of various movements is more significant. Unlike arthritis of other joints, there is no relation here between pain and sleep. It is important to remember that pain make take the form of stomach-ache, or a neuralgia radiating along nerve roots. Such pain may be unilateral or bilateral, according to the nature of the deformity, or the chief incidence of the disease being on the right or the left of the spinal column. Pain will never be felt at a higher level than the root corresponding to the diseased vertebra, except in upper cervical caries, when pain may be referred over the scalp along the course of the great occipital nerve. Other forms of pain are more striking and diagnostic. Anything which jars the vertebræ, such as running up and down stairs, jumping off a chair, a blow on the head, coughing, sneezing, laughing, or retching, a sudden push or twist to the side, a tram or 'bus journey, any of these sets up such an acute and instant pain that the individual tries hard to refrain from such movements. This restraint is in itself a feature not to be passed unnoticed when examining the patient. In other cases—for example *Case* 6—there is no complaint of pain, whether static or dynamic, throughout the whole course of the disease.

Tenderness is more often present than pain. There are two kinds, super-

ficial and deep. The former is elicited by gently touching the skin over the affected vertebræ, where there is often an area of hyperæsthesia. Deep tenderness is obtained on percussion. As with pain, tenderness never occurs above the level of the disease; if it does, some other cause must be found than tuberculosis.

If there is any prominence of the spines, it has to be ascertained whether this is merely an abnormality of the individual; or apparent, due to wasting of the spinal muscles; or pathologic, because of collapse of the bodies of the vertebræ. Wasting of muscles near the diseased part cannot always be seen, but is better appreciated by palpation, when the muscles feel soft and flabby compared with another segment elsewhere; wasting of muscles may be due to causes other than Pott's disease—for example, infantile paralysis. Hirsute changes occur later in the disease; the hair on the back then becomes longer and more abundant. Night sweats are common, and accompanied by slight fever, from 97° to 99°. There is loss of weight, but this usually corresponds with the degree of fever and sweating. Some patients lose weight very rapidly and soon become emaciated; others, even in the presence of a large psoas abscess, may remain stationary or even put on weight. Emaciation is most marked when secondary septic infection of a psoas abscess has occurred.

Great though the aid may be of a complete history in the elucidation of a correct diagnosis—negative as well as positive symptoms being duly considered—yet it is on the findings of a careful physical examination that the diagnosis is to be rendered certain. No one sign or symptom should be allowed to dominate the situation. I have seen a case sent down to Margate as tuberculosis of the spine, diagnosed as such merely by the presence of a lumbar abscess. This was an acute abscess, which healed quickly on being incised, drained, and treated with fomentations. The man otherwise was in perfect health.

The one constant sign present in all cases, is spinal rigidity. It governs the attitude and gait of the patient, and is important in determining the manner of collateral transmission of weight. It is more easily demonstrated by direct examination in children than in older patients, in whom the spine becomes progressively less supple with advancing years. A sense of insecurity is established, and there is a loss of precision in attempting to stoop and pick up small objects. Movements are slow and premeditated. All the movements of the spine—flexion, extension, abduction, and rotation—should be carried out in order, and the degree of mobility of each vertebra be both seen and felt. The vertebral spines can be made evident either by rubbing to make them stand out red, or by a drop of ink. Not infrequently in cervical caries the chin is supported in the palm of the hand, while in dorsal disease the patient in rising from a chair raises the body by the arms. There is marked inertia, patients preferring to lie about and rest rather than join in sports and games.

Every effort should be made to diagnose the disease before the onset of deformity and abscess, for the response to early treatment will be more certain and satisfactory. Deformity may consist in scoliosis, kyphosis, angular curvature, or, in the lumbar region, in a straightening of the normal forward

bend; this latter is one which is frequently overlooked. Spinal curvature may occur or increase during treatment, even while the patient is lying recumbent in bed, or may come on later during convalescence when the patient is up and about. Tuberculous bone has very little power of reproducing itself, and thus, when once the body of a vertebra has been destroyed or is very much softened by disease, contractions of the powerful ventral muscles when the patient is in bed, plus the superincumbent weight of the body when he is walking about, are very strong factors in causing collapse of the vertebral bodies and producing deformity. It is largely because of this that early operative interference is desirable. The *x* rays should be used in all cases, and it will be surprising to find in how many the clinical manifestations are dwarfed by the great extent of the disease shown in the radiograph. This is of special importance in the case of thoracic abscess in dorsal disease of the spine, especially if the radiograph taken be a stereoscopic one. Abscesses due to disease in other parts are generally easily recognized. The commonest of all is the psoas abscess, which not infrequently is bilateral. The pus in these is often so thick and caseous that fluctuation is absent, and on palpation is doughy and resembles closely a fæcal-laden bowel.

TREATMENT.

Treatment of tuberculosis of the spine and its attendant complications is all important, and unless carried out with thoroughness and care yields lamentable results. Many of those who escape death remain crippled or bed-ridden for the rest of their lives. Unlike arthrosteal tubercle elsewhere, here the disease cannot be extirpated by surgery. Although tuberculosis of bone is merely a local manifestation of a general disease, yet the gravity of the condition depends upon the extent and degree of the local disease; and when this can be treated radically, for example by subperiosteal resection, as in the case of the long bones, the happiest results are achieved. In Pott's disease, however, the anatomy is such that conservative methods alone can be resorted to. Unfortunately these often fail in their desired effect, largely through being inefficiently carried out by nurses, very few of whom really appreciate the details of strict conservative treatment. If the patient is young enough, they do not hesitate to carry him and put him in a bath, or allow him to curl up on his side at night when sleeping. I have seen this occur more than once. If an attempt is made to immobilize the spine, it should be done thoroughly; and only nurses well trained and thoroughly reliable should be employed, for success almost entirely depends on efficient nursing.

Treatment should be carried out in the open air as much as possible, and in England the East Coast climate is preferable to any other. It is dry and bracing, thereby improving the appetite and toning up the body generally. The therapeutic qualities of air are more physical than chemical, hence the better results obtained at places like Margate than in towns and villages inland. Heliotherapy is also very beneficial. Patients who are nursed night and day in the open, and who receive a maximum of sunshine, show marked improvement in general health. The action of solar rays, however, has a local as well as a general effect. One case of bilateral suppurating psoas

sinuses became apparently cured on exposure to the direct influence of the sun, where all manner of local antiseptic and surgical treatment had been applied in vain for about twelve months. The sinuses ceased to discharge, the wounds became healthy and firmly healed, induration in the line of the psoas disappeared, and the surrounding skin assumed a healthy pigmentation. This result, contrasted with the failure of previous treatment, was most astonishing. If there is any tendency to blister, the skin should be smeared with a little vaseline or protected by a thin layer of gauze. Medicines are useful if not persevered with for too long a time. Cod-liver oil and malt, with iron, arsenic, and strychnine at times, is strongly recommended along with the phosphate syrups. Plenty of good food, agreeable to the patient, should be given. Raw-beef sandwiches are exceedingly useful when the appetite is poor. They are pleasant to take, easily digested, and sharpen the appetite. The bowels must be carefully attended to, and liquid paraffin in drachm doses once a day can in most cases be depended upon to maintain a regular daily action. The thoughts of the patient should be diverted as much as possible from his illness, and he should be encouraged to take an interest in books and games. It must not be forgotten that treatment is tedious, and spread over a long period, so every advantage must be made use of to lighten the ennui of time; for patients acquiesce in treatment no matter how trying, provided they are not allowed to become mentally bored and tired. For the first twelve months the patient should be confined to bed in the recumbent position. Biscuit mattresses will facilitate nursing considerably. Three may be used, but it is better to have four, the two in the middle being half the width of those at the ends of the bed. This will enable the bed-pan to be inserted without disturbing the patient, and allow the back to be attended to while the patient is recumbent. Otherwise, if only one mattress is used, the patient should be gently rolled on to the side by one or two nurses, while another cleans and hardens the skin of the back. Too often the patient is asked to assist in being turned over, a practice entailing the use of muscles acting on the spine, thereby increasing friction and interosseous pressure in the diseased parts, which not only favours the progress of the disease but also tends to produce deformity.

The spine may be hyperextended by the use of a gas-pipe frame, a specially padded spinal board, Gauvain's back door splint, or simply by inserting a cross-piece under the mattress at the desired level. With an intelligent and careful nurse the latter method is quite satisfactory, but with others the back door splint, made to measure, has certain advantages. A roller towel over the chest kept tight with sand-bags at the sides is generally sufficient to keep the patient quiet and steady, but in some a double Thomas's hip splint or a plaster-of-Paris jacket will be necessary. It is the custom of some to treat all patients in a double Thomas's hip splint in bed for twelve months; but hyperextension cannot be satisfactorily maintained by the method, and unless the splint is made with the legs well abducted, it is difficult to avoid soiling with excretions the patient and the bed, and so this method has deservedly fallen into disrepute both with surgeons and nurses.

When a psoas abscess has formed it is best to treat this by surgery. I have seen a patient who was kept hyperextended on a spinal board for six

years in the hope that the abscess would be absorbed; yet the abscess was quite definite at the end of that time, although it had become slightly smaller. Abscesses, if they are not too large, will disappear in time; but when they have progressed and form a swelling in the back or over Poupart's ligament, it is better to open them and let the pus out. When strict aseptic precautions are taken, the wound generally heals by first intention and causes no further trouble. I generally open the abscess, mop the cavity out with gauze until the gauze returns clean, pour in an ounce of tincture of iodine, mop with gauze until the cavity is dry, and stitch up. It is a mistake to use the curette or to flush the cavity out. Occasionally a sequestrum comes away with the pus. The incision to use is one a little above and internal to the anterior superior iliac spine; I have seen the paramedian dorsal incision used once or twice, but with no happy result.

Aspiration of the abscess is a form of treatment which is strongly recommended by some authorities, with a view to avoiding septic infection and the formation of a sinus. I do not recommend this procedure. Every case of psoas abscess which had been aspirated and then sent down to Margate was admitted with a septic sinus. Often repeated aspirations are necessary to evacuate the abscess, and this after the injection of modifying solutions to liquefy the pus. The principle on which these solutions is used is hardly judicious. By setting up chemical inflammation, cells are destroyed and so liberate lysins which dissolve the thicker parts of the pus. I have known as many as eighteen injections, with as many aspirations, to have been done with little result as regards the size of the abscess. The dual effect of multiple punctures and chemical traumatism is serious in favouring septic infection. In those cases where the pus is thin, and in the absence of a sequestrum, a single aspiration may be all that is necessary; but failing this, surgical interference is decidedly better. The sequestrum which is sometimes found in a psoas abscess is seldom shown on the *x*-ray plate. The refilling of an abscess may be due to non-removal of a sequestrum.

Once a sinus has established itself as a sequel of a suppurating psoas abscess, treatment may be various, but is distinctly disappointing. Fomentations, irrigation, antiseptics, curetting, electrolysis, tuberculin, and vaccines, though all may be tried, avail little, if at all, in effecting a cure. The sinus persists in spite of all endeavours. Bismuth paste is sometimes useful. Combined with carbolic and scarlet red ointment 10 per cent, this paste is extremely useful in hastening the filling up of bone cavities, but I have not lately had a psoas sinus to try it on. The difficulty in obtaining a cure is due largely to the fact that the walls of the sinus are themselves tuberculous. The sinuses discharge less when local treatment is confined to a minimum, and attention is centred on building up the general constitution. Teeth, tonsils, and the bowels should receive special care, as they are foci whence continued septic infection of the blood is maintained. I have not seen the effect of iliosigmoidostomy on a psoas sinus, but I have performed the operation on two occasions for morbus coxæ with sinuses, and there was marked improvement in each case both as regards the local disease and the general health. Enucleation of tonsils was likewise attended by constitutional improvement.

Symptoms referable to pressure on the cord are an indication for hyper-extension and weight traction on the head and neck. The operation of laminectomy is seldom required, the symptoms quickly subsiding when more complete immobility of the spine is obtained.

If after twelve months there is complete cessation of symptoms and fever, and in the absence of abscess and sinus, arrangements can be made for ambulatory treatment. Some form of spinal support will be necessary, and the best undoubtedly is the plaster jacket. Failing this, a celluloid jacket made to fit a correctly-taken cast should be used. Poroplastic and other mechanical supports are inadequate. The jacket should be applied by the surgeon in all cases, and if of celluloid he should superintend the taking of the cast; nurses and many splint makers are lacking in that special knowledge of the skeleton without which it is impossible to construct a support mechanically sound in maintaining immobility of the spine. I have seen a representative of a well-known firm, who was sent down to take a cast preparatory to making a spinal splint for upper dorsal disease, set about his task in such a way that he would turn out a very nicely finished corset, but one totally inefficient for the purpose intended, as in front it reached no higher than the nipple, and was unconnected over the shoulders with the back. To limit movements of the spine to the minimum, it is absolutely essential to fix the shoulder and pelvic girdles. The plaster, therefore, should be accurately moulded over the pubes in front, reach laterally midway between the crest of the ilium and the trochanter; while above, it must be moulded well over the clavicles and shoulders. If the disease affects the upper dorsal or cervical spine, the head also must be fixed, and this is attained, not by the use of a collar or chin support, but by moulding accurately under the inion and mastoid processes, and continuing the plaster round the forehead. A plaster jacket thus put on permits of the presence of a large ventral window without endangering the stability of the support, and is not unduly heavy nor uncomfortable to the patient. The plaster should be worn for about twelve months, after which for another twelve months it should be replaced by a lighter celluloid jacket.

Treatment of Pott's disease of the spine occupies a period of about three years in favourable cases: if suspended sooner because of apparent arrest and cure, relapses are prone to occur. Conservative treatment of bone tuberculosis has an end not unlike that of similar treatment of an inflamed appendix, where, though the active symptoms are successfully combated, yet the disease in a large majority of cases merely becomes quiescent and latent, ready to flare up on the slightest provocation. Cessation of activity is not a cure; and too many cases are seen of chronic tuberculosis supervening years afterwards on the site of a lesion which was apparently a healed focus of subacute tubercle, to justify one in claiming anything more as a result of conservative treatment, no matter how successful this may appear to be at the time.

Perseverance in conservative methods should with advantage be prolonged over as long a period as possible, and if this could be for the life-time of a patient, the result would be not far removed from a cure. By the introduction of the bone graft, an operation devised by Allbee, of New York,

continuous conservative treatment has been made practicable, and the results, from a theoretical consideration, should far surpass those of discontinuous treatment, which has had such a varied success in the past. The operation is not difficult, and the technique is fully described in *Case* 1. The graft from the tibia can be removed with either a twin circular saw, adjusted to the desired width, or with a single circular saw, worked from a motor held in the hand, as advised by Allbee, or through a flexible shaft from a distant motor: this latter method has the advantage that the whole shaft, handle, and saw can be sterilized by boiling. The instrument is lubricated with sterilized oil before being used. Care must be taken to prevent the saw becoming too hot, either by continuous saline irrigation or by reducing the rapidity of rotation, otherwise the cells in the neighbourhood of the saw-blade will be destroyed. Marrow, endosteum, cortical bone, and periosteum, should all be included in the graft. If the curvature is pronounced, the graft can be cut to fit, or made to bend by a series of undercuts on the concave side. When in position, the ends of the graft may be crushed with necrosis forceps so as to liberate osteoblasts, a proceeding, according to Macewen, which favours osteogenesis. One of three fates may overtake the graft: (1) It may remain viable, and become incorporated with the spinous processes; (2) It may be absorbed and replaced by new bone; (3) It may sequestrate.

Success depends on the maintenance of absolute asepsis throughout the operation. Fingers should never be allowed to intrude in either wound. If the operation is successful, a firm buttress of bone is formed welding together the spinous processes and prohibiting for all time any movement of the diseased parts. When the curvature is but slight, the appearance of the deformity becomes much improved, while any increase is rendered impossible, for the bodies in front collapse only to the extent that separation of the spinous processes behind allows. The splint thus formed is permanent, and more efficient than any form of mechanical fixation. The advantages accruing are obvious. Patients need no longer be confined to bed for more than six or eight weeks, constitutional treatment can be carried out under improved physiological conditions, and recourse to heavy and expensive means of spinal support becomes needless.

I have done the operation in six cases. Reports twelve months later are very satisfactory in three. The last is too recent to infer success from it. Two cases were very ill, and complicated by the presence of suppurating psoas sinuses, and so far have shown no marked benefit from the operation. Allbee himself records a hundred successful cases.

DESCRIPTION OF CASES.

Case 1.—E. R., male, age 11, admitted to hospital under Dr. Sawers, May 8, 1914, discharged as cured Feb. 12, 1915.

The patient had been under treatment at the Miller Hospital, London, for one month before being sent down to Margate, and had had a psoas abscess aspirated. On admission, he was found to be well nourished and in a fair state of health. There was well-marked angular curvature of the lumbar spine, with immobility, pain, and tenderness. A large psoas abscess was present on the side which had been aspirated. *X* rays revealed extensive disease of the bodies of the 1st, 2nd, and 3rd lumbar vertebræ, with collapse, resulting in angular curvature and scoliosis. The intervertebral

discs between the last dorsal and the 1st lumbar, and between the 3rd and 4th lumbar, vertebræ were also diseased. The temperature ranged from 98° to 99°. There was no disease of the lungs or glands.

Four days after admission I operated on the psoas abscess, which was evacuated, cleaned with gauze, and stitched up. No antiseptics nor curetting were employed. The wound healed by first intention. The patient was treated in the full recumbent position, with abundance of cod-liver oil, nourishing food, and fresh air. Occasionally the temperature showed wider excursions, rising from 97° in the morning to 99·4° in the evening. The psoas abscess re-formed, but was not operated upon.

Seven months after the patient was first brought under treatment for tuberculous disease of the spine, I performed an Allbee's operation on him. The anæsthetic was given by my colleague, Dr. Poyser, with the patient in the prone position, shoulders and pelvis resting on sand-bags, so as to secure free respiration. The skin of the back and leg was prepared with tincture of iodine 3 per cent. A semilunar incision was made through the skin, with the convexity to the right, and a flap resected, thus uncovering the lumbar spines well above and below the level of the diseased vertebræ. The tips of the spines and the interspinous ligaments were divided longitudinally by a strong scalpel. The spines were then split with a fine chisel and mallet, to a depth of a quarter of an inch, and the right half of each was fractured. A gutter five inches in length was thus formed, which was firmly packed with gauze wrung out of saline at 115° to arrest hæmorrhage. The wound was then covered with gauze and a sterile towel, while attention was being given to the removal of the graft from the left tibia.

FIG. 102.—*Case* 1. Skiagram taken seven weeks after the operation. The graft is shown united to the spines of the five vertebræ. When the spine was palpated there seemed to be a good deal of callus thrown out which is not shown on the plate.

The leg was flexed, and a skin flap reflected from the shin. The size of the graft, which had been measured with a probe, was marked out on the periosteum with a scalpel, and the bone was divided with an electric circular saw. The graft was five inches long, a quarter of an inch wide, and included the whole thickness of the bone cortex down to the marrow, periosteum and endosteum, both being preserved. The graft was immediately transferred to sterilized saline at 115°, and the wound packed with gauze and covered.

The packing was then removed from the gutter which had been made in the spine, and the graft inserted. The graft was so arranged that endosteum was in apposition with a raw bone surface on one side of the gutter, and periosteum on the other side. Care was taken throughout not to touch any part of the bone with the fingers. The spinous processes were sutured over the graft with prepared kangaroo tendon, and the interspinous ligaments with fine silk. Fascia was then sutured over the line of the spine with interrupted silk, the skin flap accurately readjusted, and a dry sterilized gauze dressing applied. The wound of the leg was then repaired.

The whole operation lasted sixty minutes, with very little shock. Stitches were removed a week later, the wounds healing by first intention. For six weeks after the operation the patient was confined to bed in the recumbent position, and then raised gradually on a back rest, and allowed to turn about in bed. The spine was free from pain and tenderness, and felt as though an abundance of callus had been thrown out around the graft. Ten days later, seven weeks after the operation,

the patient was up sitting in a chair, and soon afterwards was allowed to walk about. No further operation was needed for the psoas abscess, which gradually became absorbed. The patient gained in weight, the temperature became normal and steady, and there was no complaint of pain or weakness. He was discharged from the hospital Feb. 12, 1915, seven months after the operation, as cured. For over two months he had been running about the fields of the hospital and playing with the convalescent patients, as though the disease of the spine caused him no inconvenience whatsoever. A radiograph taken six months later shows the graft firmly united in position.

Case 2.—A. H., male, age 4½, was admitted to the Royal Sea-bathing Hospital, under Mr. Sutcliffe, March 27, 1914, having apparently had no treatment previously. About six months ago the child was noticed to cry out with pain when walking, and to rest his hands upon his knees.

On admission, there was found to be present a marked dorsi-lumbar curvature, affecting the 11th and 12th dorsal and the 1st lumbar vertebræ. Scoliosis was present. On the right side there was a large psoas abscess filling up the greater part of that half of the abdomen. There were no pressure signs beyond a brisk knee-jerk on the right side, plantar response of the big toe being flexor on both sides, and ankle-clonus absent. The general condition of the patient was poor. Temperature was normal. The psoas abscess was opened and evacuated by Mr. Sutcliffe on April 7. The wound healed by first intention.

For the first three months the temperature remained normal; for the next five months it ranged from 97° in the morning to 99·4° in the evening, occasionally reaching 100°. The patient meanwhile was being treated in the recumbent position with counter-extension on a back door splint, as designed by Mr. Gauvain, of Alton, which I had made for him. This splint facilitated nursing considerably, and was very comfortable to the patient. It was worn for twenty-five weeks, until Oct. 22, 1914, when I transplanted a graft from the tibia into the spine. Recovery from this operation, which lasted fifty minutes under chloroform-ether anæsthesia, was uneventful. There was little shock and no after-pain. The back door splint was dispensed with after the operation, but the patient was kept in the full recumbent position for eight weeks, when he was allowed to begin moving about in bed. For the last seven weeks he has been sitting up in a chair, and now, April, 1915, is beginning to walk about. The psoas abscess has not re-formed. As the result of the graft in the spine, the dorsal curvature seems less prominent than before. The reflexes are normal and equal, and no complaint is ever made of pain or tenderness.

The report in August was very favourable; there was no pain, and the patient was enjoying a freely active life.

Case 3.—G. S., male, age 19½, was admitted under Dr. Heaton, Sept. 4, 1914, and discharged April 16, 1915. The disease had been in progress for about two years. The patient had previously been treated for nine weeks in the Royal Orthopædic Hospital, and at home, for tuberculous disease involving the lower cervical and upper dorsal vertebræ. The condition was said to be fairly acute, but one likely to be arrested by treatment. Glands and lungs were clinically free from tuberculous trouble.

On admission, the patient was suffering considerably from pain and tenderness along the spine. Dorsal kyphosis was very marked. The patient's general condition was fair. There was no psoas abscess present. *X* rays revealed extensive destruction of the bodies of the dorsal vertebræ; corresponding to the point of maximum curvature two bodies were altogether missing, and a gap of about half an inch intervened between the diseased bodies above and below. The deformity had been progressive, and from the appearance of the radiograph was likely to continue so.

Patient was treated along the usual conservative lines in the recumbent position in bed, for three weeks, without any abatement of pain and tenderness. In the hope of arresting these symptoms and preventing an increase in the deformity, I implanted a tibial graft in the spine on Sept. 9, 1914. The graft was five inches in length, and by means of multiple cross cuts could be bent to fit the convexity of the

spine. The skin flap in one place developed a partial bed sore, but this was kept dry with dressings of picric acid 3 per cent in alcohol, and fortunately no sepsis occurred to endanger the vitality of the graft. The effect of the operation in alleviating pain and tenderness was immediate. On Dec. 27, eight weeks after the operation, the patient was raised on a back rest, and on Jan. 15 was allowed to get up. He was discharged from hospital on April 15, having in the meantime been walking about free from pain and without any other support than the graft. The patient has put on weight since he has been up and about. He himself is very pleased with the result of the operation.

Case 4.—H. V., male, age 6, admitted under Dr. Sawers, Aug. 11, 1914, discharged April 15, 1915. The patient was said to be suffering from bilateral morbus coxæ. There was a discharging sinus above Poupart's ligament on each side. The disease had been progressive since December, 1913. He had been treated at an infirmary for seven months. Favourable progress was said to have occurred. There was no clinical evidence of tuberculosis elsewhere.

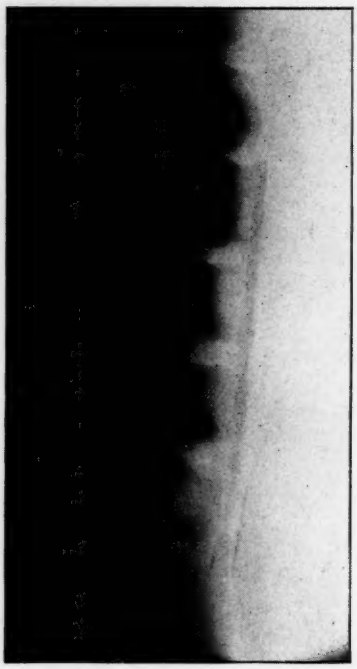

FIG. 103.—*Case* 4. Skiagram taken four months after the operation, showing the graft.

On examination, the patient was very anæmic and toxic. There was a profuse discharge of thick pus from each sinus. Angular curvature of the lumbar spine was present, and was first noticed about April. The left hip was markedly flexed. There was pain and tenderness in the lumbar spine. Movements of the hip-joints, adduction, abduction, and rotation in a small arc of a circle were perfectly free and devoid of pain. An *x*-ray photograph was taken of the hip-joints and the spine. The former showed no evidence of disease. In the spine, disease was present in the bodies of the last dorsal and 1st, 3rd, and 4th lumbar vertebræ, with the intervening discs. The 2nd lumbar vertebra was free from disease. Thus an unusual condition was present, there being two separate foci of disease, with a healthy vertebra intervening. Temperature ranged from 97° to 101°.

The patient was treated along the usual constitutional lines adopted in the hospital, and extension was applied to the left hip to correct the flexion. As pain and tenderness, suppuration, and fever showed no abatement, I performed an Allbee's operation on Oct. 1, transplanting a graft seven inches long from the tibia. The wounds healed by first intention. The general condition of the patient improved, and the temperature became steadier, and less frequently rose above 100°. The psoas sinuses showed no signs of healing. The patient was never allowed up because of the temperature, and was discharged from hospital on April 14, 1915, as being likely to receive no further benefit from a more prolonged stay. Operation in this case was not a success as regards the general course of the disease. It is true that the patient felt better in himself, and had a greatly improved appetite, but the effect on the amount of psoas suppuration was insignificant. He has since been lost sight of.

Case 5.—J. T., male, age 9¾, admitted under Mr. Sutcliffe, July 4, 1914, discharged April 17, 1915. The disease is said to have started about two years ago. The patient was treated at Great Ormond Street Hospital, London, where a psoas abscess had been opened. There was said to be lumbar caries, psoas sinus, and the presence of tubercle bacilli in the urine. The physical condition was fair. The abscess had been repeatedly aspirated before being incised. There was no clinical evidence of disease in the lungs and glands. The kidney was said to be tuberculous.

On admission, the patient was running a septic temperature from 99° to 102°, with pulse of 136, and respirations about 30 per minute. The cheeks were flushed. The skin round the incision into the psoas abscess was inflamed, and pus was being discharged profusely. There was marked pain and tenderness of the lumbar spine, with kyphosis. There were no genito-urinary symptoms of tuberculosis, and no tubercle bacilli nor pus were found in the urine. The patient was treated in the recumbent position in bed, until Aug. 21, when he was hyper-extended on a spinal board. This was more comfortable for the patient, but he still complained of a good deal of pain and tenderness. The abscess showed no signs of healing, while the temperature was irregular, frequently ranging in the week from 97° to 102°.

On Oct. 22 I removed a tibial graft and implanted it into the spine. The operation lasted forty-five minutes and was attended with but little shock. The anæsthetic was

FIG. 104.—*Case* 5. Skiagram taken three months after the operation. The graft was fixed to six spines. Although the skiagram shows the lower end away from its attachment, there was no evidence of this on palpation.

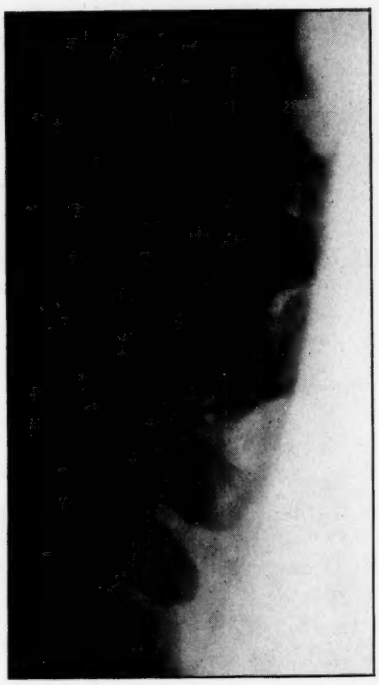

FIG. 105.—*Case* 6. Skiagram taken one month after the operation, showing the graft.

C.E. mixture. The wounds healed by first intention. About the beginning of December, the patient showed signs of tuberculous peritonitis, with vomiting, diarrhœa, and great abdominal pain. Meningeal symptoms, headache and strabismus, were also present for a time. Temperature ran up to 103°, and the general condition was so bad that the patient was thought to be dying. In January, however, there was much improvement, and the temperature became more regular and settled.

Patient was discharged from hospital on April 16, as being likely to benefit no further from a stay at Margate. The general condition was now fair, but the temperature still showed excursions from 98° to 100°.

About two months after the operation on the spine a bed-sore developed at the site of the implanted graft; but it responded to treatment, and became

healed without involving the vitality of the underlying bone. On discharge, the wounds both of the spine and tibia were firmly healed.

In this case the only improvement to be noticed was the complete and early disappearance of pain and tenderness along the spine. Suppuration in the psoas abscess remained unaffected, and septic absorption continued to sap the patient's constitution and power of resistance.

The radiograph taken three months later shows the graft firmly united to the spinous processes along the line of curvature.

Case 6.—R. H., age 6, was admitted to the Royal Salford Hospital, May 17, 1915, under Mr. Macalpine. For a year previous to admission the patient had been treated for sarcoma of the left iliac bone. There was an indefinite mass occupying the left iliac fossa and extending into the loin. *X* rays had had no effect in reducing the size of this mass. There was no complaint of pain. About a month before admission acute curvature of the lumbar spine was noticed.

I examined the patient and found a fluctuating psoas abscess on the left side, extending from Poupart's ligament to the loin. A skiagraph showed disease of the 2nd lumbar vertebra, the body of which had completely disappeared. The patient was admitted to hospital, and on May 18 I opened the abscess. A sequestrum came away with the pus. The wound was closed, and healed by first intention. The patient was kept recumbent and treated with hyperextension in bed.

On June 15 I removed a graft from the tibia three inches long and a quarter of an inch wide, and inserted it into the spine. The graft was a thick one and contained a good deal of marrow. The wounds healed by first intention. The skiagraph taken one month after the operation, shows the graft firmly united in position to the spines of four vertebræ. Six weeks later the patient was up and running about. There was no pain.

Seen six months later, patient was progressing very satisfactorily indeed.

In conclusion, I wish to thank Mr. Sutcliffe, Dr. Sawers, Dr. Heaton, and Mr. Macalpine for giving me their cases to operate on, and to Dr. Bythell for the excellent radiogram of *Case* 6.

TRAUMATIC AND ARTERIO-VENOUS ANEURYSM.

A THIRD SERIES OF CASES—*continued from Vol. III, page* 496.

XV.—SEVEN CASES FROM THE ROYAL HERBERT HOSPITAL.

By R. JOCELYN SWAN.

Case 1.—**Traumatic Aneurysm of the Superficial Femoral Artery. Ligature, followed by Aneurysm of Profunda Artery and Gangrene.**

Lance-Corp. F. was wounded on Sept. 11, 1914, by a rifle bullet which passed obliquely through the right thigh from an entrance three inches below the mid-point of Poupart's ligament, and emerged by a small wound on the inner and posterior aspect of the mid-thigh. On admission to the hospital on Sept. 17, he complained of severe aching pain in the right thigh. There was a large swelling occupying the middle third of the anterior and inner aspect of the thigh, with expansile pulsation and distinct systolic thrill, whilst a very loud rumbling bruit could be heard on auscultation. This bruit was loudest over the swelling, and was soon lost in an upward direction, but could be distinctly heard in the lower thigh and over the femoral condyles. Upon pressure on the common femoral artery, the pulsation and thrill were arrested, the pain was markedly decreased, and the swelling almost entirely disappeared. The dorsalis pedis pulse was palpable. Temperature was normal, and there was no evidence of sepsis.

The swelling increased in size, and the pain in the leg became more severe; therefore on Sept. 21 the superficial femoral artery was tied above the swelling in Scarpa's triangle and again in Hunter's canal below it. There was much extravasated blood in the sartorius muscle, making it firm and rigid, and obliterating the anatomical lines in the distal ligature operation. The femoral vein did not pulsate and was not ligatured. The wound healed primarily and the swelling practically disappeared.

Progress was uneventful until Oct. 7, when a tense swelling was again found in the middle of the thigh. There was no reddening of the skin, and no pulsation could be felt in it; but a distinct systolic bruit could be heard over it. The leg was maintained in a raised position; but gradually the swelling grew, and the circumference of the thigh over it increased from 17 inches on Oct. 10 to 19½ inches on Oct. 23. On that date the pain was more severe, a distinct pulsation could be felt, the foot was cold, and its cutaneous sensation was deficient. Pressure on the common femoral did not cause decrease in the size of the swelling.

On Oct. 24 an incision was made over the swelling, and a large cavity full of blood-clot was found. On removing the clot, profuse hæmorrhage occurred

from the depth of the wound. The cavity was firmly packed with gauze and the limb bandaged, and the patient was given large doses of morphia.

On Oct. 27 the gauze was removed under an anæsthetic, when furious hæmorrhage occurred from the lower and deep part of the wound—evidently from the profunda artery close to the femur. A large clamp was put on, but I was unable to apply a ligature owing to the friability of the tissues. The clamp was left on, as the patient's condition was serious, and the greater part of the wound closed. The clamp was removed on Oct. 31 without further hæmorrhage; but the foot and leg gradually became shrivelled from dry gangrene, necessitating on Nov. 9 amputation of the limb through the upper third of the thigh. The patient made a good recovery from the operation.

Remarks.—In this case the bullet must have opened the superficial femoral artery, and at the same time injured the profunda, so that the latter gave way under the stress of the collateral circulation, causing a second traumatic aneurysm. The swelling caused by the femoral aneurysm practically disappeared after ligature of the superficial femoral, and it was not until sixteen days later that the recurrent swelling was noticed. This rapidly increased in size, and operative interference was forced by the threatened gangrene of the foot. There was never any sepsis in the area of the wound. In the rush of work at this time the leg was not preserved, and no dissection was made of the vessels.

Case 2.—**Traumatic Aneurysm of the Popliteal Artery. Proximal Ligature.**

B. was wounded on Sept. 11, 1914, by a rifle bullet which perforated the upper and posterior part of the left leg. There was not much bleeding from the wound at the time. On admission to the hospital on Sept. 28, there were two small scars of punctured wounds on the upper part of the left leg, one immediately posterior to the inner border of the tibia two inches below the interarticular interval of the knee, and another one inch behind and below the head of the fibula. There was a tense swelling occupying the lower part of the popliteal space and upper part of the calf, deep to the gastrocnemius muscle; over it an expansile pulsation was felt, and a distinct, soft, whiffing bruit heard. There was no thrill; but the pulsation was arrested upon pressure being made on the common femoral artery, though the size of the swelling was not decreased. There was no pain in the leg, and a feeble pulse could be felt in the dorsalis pedis artery.

On Sept. 30 the popliteal artery was tied in the upper part through an incision between the tendons of the adductor magnus and semimembranosus.

By Oct. 10 the wound had healed primarily, the tense swelling of the calf had gone down, and the area was quite soft. The circulation in the foot was good.

Oct. 20. No swelling found in the leg now. The circulation in the foot is good. The patient is walking about.

Case 3.—**Traumatic Aneurysm of the Popliteal Artery.**

Sapper S. received multiple wounds from a bomb explosion in France on Feb. 16, 1915. After running about fifteen yards he felt a sudden pain in the lower part of the left thigh, and thought he had been wounded

again. He fell down with his left leg flexed, and found he could not straighten it. When admitted to hospital on March 9, the knee was maintained flexed, and attempts to straighten it caused pain. There were several small scars of wounds on the buttocks and posterior aspect of the thigh and leg, but all were healed. Occupying the upper part of the popliteal space, and extending upwards in the lower third of the thigh on the inner side, there was an oval-shaped swelling in which was felt an expansile pulsation, arrested when pressure was made on the femoral artery, but with only very slight decrease in the size of the swelling. There was no discoloration of the skin over it, and no thrill was felt. A distinct bruit could be heard over the whole area, most marked on the inner aspect of the lower thigh, loud and blowing in character, and systolic in rhythm. The foot was cold, and no pulse could be felt in the posterior tibial or dorsalis pedis arteries. The circumference of the thigh over the swelling was one and three-quarter inches larger than that of the other leg.

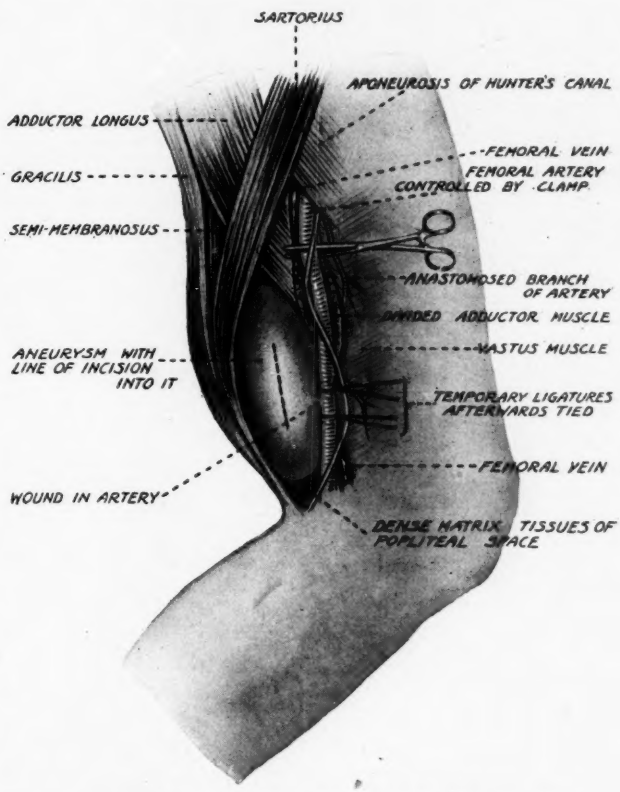

FIG. 106.—Aneurysm of the popliteal artery.

Radiography showed a small metallic fragment in the antero-internal aspect of the thigh four inches above the knee-joint, with a minute particle in the postero-external aspect, showing a possible track of the bullet across the line of the popliteal vessels.

On March 17 the tumour was distinctly larger in the long axis, and was painful. An operation was therefore advised.

OPERATION, March 18.—An incision was first made over the lower part of Hunter's canal, and the femoral artery exposed, and controlled by a light clamp. The incision was then prolonged over the inner side of the popliteal space, where the tissues were found to be very matted from extravasated blood. The muscles were separated backwards and the covering of the aneurysm freely exposed, when it was found that the opening in the adductor magnus was spread out over it. The muscle was divided, and the main artery found to pass down in front of the aneurysm, to which it was very adherent. The artery was next exposed below, and traced upwards as far as possible in the matted tissues; two temporary ligatures about one inch apart

were then passed round the vessel on each side of the aneurysmal opening (*Fig.* 106). These were pulled upon to control the circulation in the vessel, and the sac was opened, a quantity of clot and fluid blood being removed. On relaxing the clamp and the upper ligature, a small opening was found on the inner side of the vessel; but attempts to sew this up with very fine thread failed, owing to the friable tissue. Accordingly, the two temporary ligatures were tied. The sac was swabbed out with saline, all bleeding points were arrested, and the wound was sewn up without drainage. The whole leg was wrapped in wool.

By April 1 the wound had healed primarily, and there was no swelling; by April 30 the patient could straighten the knee to full extension.

He reported to me on July 10. All movements of the knee were perfect. There was no thickening to be felt under the wound, the foot was warm, and the dorsalis pedis and posterior tibial pulses were easily felt.

Remarks.—In this case the operation was designed to sew up the actual opening in the vessel, the artery being controlled on each side before the aneurysm was opened. The actual opening in the vessel was small, but the tissues of the arterial coat were so friable that the suture tore through them at once. Had I taken up more of the arterial wall in order to obtain a hold in firmer tissues, the lumen of the artery would have been blocked, and I deemed it safer to ligature the main trunk immediately above and below the opening. It is interesting to note that the injury to the artery was caused by a minute fragment of metal, and that the bleeding into the tissues occurred immediately on receipt of the wound, and later formed a distinct sac with smooth endothelial lining.

Case 4.—**Traumatic Aneurysm of the Brachial Artery. Opening Sutured without Ligature of Main Trunk.**

J. C. was wounded on March 10, 1915, by a bullet passing through his right arm from a point on the inner and anterior aspect two and a half inches below the pectoral tendon, to a point on the mid-posterior aspect three inches above the olecranon process. There was a good deal of bleeding from the entrance wound, and the hand became cold and numbed at once.

The wounds healed quickly; but in the first week in April a swelling became apparent on the inner surface of the arm, and was incised, blood-clot being removed. Later, the swelling reappeared. When admitted to the hospital on May 11, there was a large fusiform swelling occupying the inner part of the arm, chiefly on the anterior aspect, but also on the posterior, apparently deep to the triceps muscle (*Figs.* 107, 108). This swelling had recently increased in size, and was much softer in front than posteriorly. Throughout the mass a distinct expansile pulsation, arrested by pressure upon the axillary artery, could be felt; pressure above only diminished the size of the swelling to a small extent. No thrill was present. On auscultation, there could be heard a loud, systolic, whistling bruit over the whole surface of the tumour, most marked anteriorly, not traceable over the vessels above or below the tumour. The radial pulse was not felt. The hand was cold and of a bluish colour, and the superficial epidermis was peeling. There was no anæsthesia of the hand or forearm; all individual muscular movements were good.

Radiography showed no fracture of the humerus, and no metallic fragments were present in the arm. During the following week the swelling became slightly larger, and there was some pain in the arm.

FIG. 107.—Aneurysm of the brachial artery, showing the anterior aspect of the arm.

OPERATION, March 19. —An incision was first made along the axillary fold, and the brachial artery exposed, a loop of thread being passed round it and left untied. A second incision was then made in the lower part of the arm, but much difficulty was found owing to marked venous congestion and also from matting of the tissues from the extensive blood extravasation. The brachial artery was exposed, but no pulsation could be felt in it; a temporary loop of thread was passed round it. The two incisions were next joined by another passing over the tumour, and the skin and fascia reflected. The ulnar nerve was easily separated from the aneurysm, but separation on the outer side was much more difficult owing to dense fixation of the mass to the biceps. The median nerve and the brachial artery were separated downwards, and a light clamp was fixed on the vessel; the sac was opened and a mass of clot, some recent and some old, turned out. The cavity was large, and extended behind the humerus in the musculospiral groove, the sac being too extensive to remove. After emptying the latter, the clamp on the artery was released, when a jet of blood pumped out from a small opening on the outer aspect of the brachial artery. The clamp was reapplied, and a circular suture of very fine thread passed in the arterial wall around the opening and tied. On releasing the clamp there was no further bleeding. The area was flushed out with hot saline, the lower thread was removed from the artery—the upper being retained and brought out through the wound in order

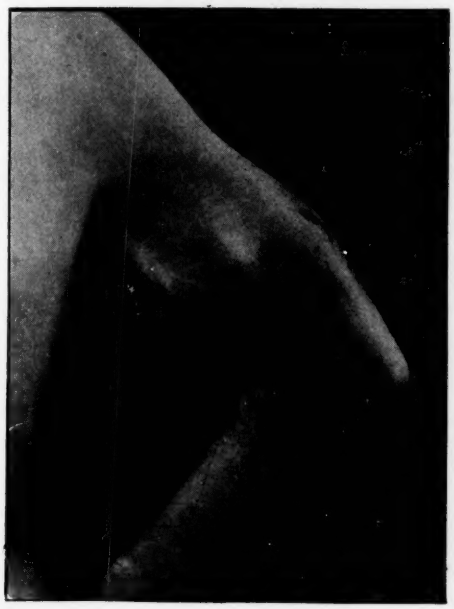

FIG. 108.—The same case as *Fig.* 107, showing the posterior aspect.

to control any bleeding that might occur—and the incision was sewn up without drainage.

On the next day the radial pulse could be distinctly felt.

On May 23 the wound was making excellent progress, and the upper thread was removed. On May 31 the wound was firmly healed. There was no swelling under the scar. The radial pulse was small, but of fair volume. The hand was not so cold, and was a good colour.

July 20.—The patient can now do anything with his arm; the radial pulse is good, but slightly smaller than on the left side.

Remarks.—This was a large traumatic false aneurysm of the brachial artery, in which a small opening was found leading directly into the sac. I was able to obliterate the opening by direct suture without blocking the lumen of the vessel—in fact, the radial pulse could be felt on the day following the operation. The sac was too extensive for removal, and I am inclined to think the whole sac may be safely left in these cases; for not only would its removal be difficult amid the matted surrounding tissues, but its presence makes little difference in the progress of the case. I left the upper loop of thread around the artery in order that any subsequent bleeding from the arterial suture might be controlled; but it was not required.

Case 5.—**Traumatic and Arterio-venous Aneurysm of the Superficial Femoral Artery.**

C. was wounded by a rifle bullet entering the right thigh at the apex of Scarpa's triangle on May 8, 1915. There was no profuse bleeding. On admission to hospital on May 10, a radiograph showed a fracture of the femur two inches below the small trochanter, with slight displacement of the lower fragment inwards, and a deformed rifle bullet was present on the inner side of the fracture.

On May 15 the upper part of the thigh was found to be swollen and tense. Just below the wound a distinct thrill could be felt over the main vessels for about one and a half inches, resembling fine emphysematous crackling. This thrill was systolic in rhythm and was easily effaced by pressure on the artery above. On auscultation, a loud, rumbling bruit could be heard over the whole anterior surface of the thigh and in the popliteal space, but was most marked just below the wound. The posterior tibial pulse was easily felt. The fracture was fixed with extension apparatus.

On June 23 the local swelling had gone down, but the thrill was much more perceptible, and in a larger area. It was traceable both upwards and downwards in the line of the vessel, and a roaring bruit was heard over it. The posterior tibial pulse was still palpable.

Operation, by Lieut. R. Sedgwick.—The superficial femoral artery was exposed above, when pressure upon it arrested the pulsation. The artery was again exposed in Hunter's canal, which was found much matted by extravasated blood, and temporary ligatures were applied. On tracing the vessel between them, a sac the size of a walnut was found on the outer and superficial aspects of the femoral artery, and in addition a small communication was found directly between the artery and vein. The vessels were ligatured above and below, and about one inch of both resected. No search

was made for the bullet. The patient made an excellent recovery, and there was no subsequent trouble with the foot.

[I am indebted to Lieut. Sedgwick for the notes of this case, which he asked me to see with him.]

Case 6.—**Traumatic Aneurysm of the Common Carotid. Internal Jugular Vein pierced and thrombosed. Artery and Vein resected. Vagus Nerve fixed in adhesions.**

J. M. was wounded Oct. 3, 1915, by a shell fragment entering on the right side of the neck in the upper angle of interval between the sternal and clavicular heads of the sternomastoid muscle. There was profuse hæmorrhage from the wound, and he says he felt that his arm was blown off. He was unable to move his right arm for about twenty-four hours. There was no exit wound of the missile.

On admission to hospital, on Oct. 15, there was an oval-shaped swelling under the healed scar of the wound, measuring one and three-quarter inches by one inch. There was no thrill, but a distinct expansile pulsation was felt over it. The temporal pulse on the right side was good. On auscultation, a loud, blowing bruit was heard, systolic in rhythm, most marked over the swelling, and traceable upwards in the neck a short distance. The right pupil was small and did not react to light. The patient complained of a tingling sensation in the thumb, index and ring fingers, but there was no anæsthesia, and all movements of the hand and arm were good. He was unable to hear any bruit himself. Radiographic examination showed a fairly large, oblong, metallic fragment lying in the interval between the transverse processes of the fifth and sixth cervical vertebræ.

Oct. 30.—The aneurysm was certainly larger. On slight pressure over it a fine thrill could be felt. The mass seemed to project more in the posterior triangle of the neck. The right pupil remained small. The voice was unaltered.

Operation, Nov. 4.—An incision was commenced low down in the neck over the border of the sternomastoid, and the latter exposed. On reflecting the muscle, a great deal of dense matting of tissues from extravasated blood was found, obliterating the anatomical planes. There was very marked pulsation of the vessels of the root of the neck. The carotid sheath was opened, and the common carotid artery and internal jugular vein were exposed; a ligature was passed around each and left untied. The incision was prolonged upwards over the tumour, and the sternomastoid muscle reflected, when great difficulty was again found in identifying the structures owing to the dense matting of the tissues. Dissection was carried above the swelling, when the internal jugular was exposed, and found to be much thickened and thrombosed. The common carotid was exposed at the bifurcation, and a ligature passed loosely around the vessel. On dissection, the tumour was found to be placed behind the common carotid, which could be seen lying superficial to it, densely fixed and incorporated in the aneurysm. The latter was separated on the inner side as much as possible, but with much difficulty, as also on the outer side. The vagus was exposed above and below the aneurysm, and traced upwards and downwards, when it was found to be densely bound down in the matted tissues. It was found impossible to dissect the aneurysm

from the tissues in order to close the wound in the artery, and the ligatures around the artery and vein above and below the aneurysm were therefore tied. The artery was then opened vertically, when a large oval opening was seen in the posterior aspect, partially filled with blood-clot, and leading directly into the sac behind the vessel. The vagus was further separated, the sac being opened and blood-clot removed, and the piece of artery and vein between the ligatures excised (*Fig.* 109). The piece of shell-casing was found firmly fixed in the side of the body of the fifth cervical vertebra, and removed. The operation area was swabbed out with saline, and the wound closed. The wound healed primarily, and convalescence was rapid. There was no symptom of cerebral anæmia, and no trouble at any time with the left arm. The patient left hospital well on Dec. 1, and when finally seen on Jan. 3, 1916, was still quite well, but the right pupil was still smaller than the left.

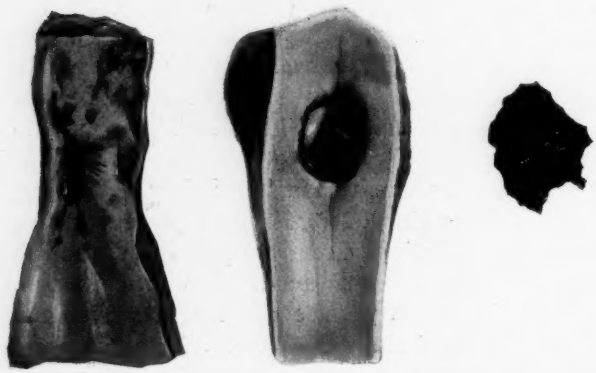

FIG. 109.—About two and a half inches of both artery and vein were removed. In the posterior aspect of the artery is an oval-shaped opening partly filled with clot. The edges of the opening are rolled and friable. The aneurysmal sac is placed behind the artery, is thin-walled, and loculated. The vein is normal in the lower part, but at the level of the arterial injury shows two linear scars with surrounding ecchymosis. The endothelial lining is much thickened, and the upper part of the vein is thrombosed. There was no communication between the artery and vein, or between the vein and the aneurysmal sac.

REMARKS.—The operation was commenced with the idea of closing the opening in the artery, but great difficulty was encountered in separating the tissues about the injury, owing to the organization of the extravasated blood. The vagus nerve was densely adherent to the aneurysmal sac; and had I been able to expose the opening in the artery from the aneurysmal side, it would have been impossible to suture the opening, owing to the size of the latter and the friable edges, without effectually blocking the lumen of the vessel. It is remarkable that the fragment should have pierced both sides of the internal jugular vein, as well as wounded the artery, without there being any direct communication between the vein and the aneurysm; and also that fatal hæmorrhage should not have occurred from such a large wound of the common carotid. Although the injury was inflicted by a fragment of shell, there was no sepsis in the wound.

Case 7.—**Subclavio-Axillary Aneurysm appearing six months after a Gunshot Wound of the Infraclavicular Fossa.**

A. J. was wounded by several small shell-fragments on Aug. 18, 1915. He was admitted Aug. 30 with two small punctured wounds in front of the left shoulder, one at a point 1 inch below the clavicle and 2½ inches from the sternoclavicular joint, and the second an inch above the lower border of

the pectoral fold; there had been smart hæmorrhage at the time of the wound. Radiography showed the presence of two small metal fragments, one just below the clavicle and the other in the axilla. There was motor paralysis of the biceps muscle, and loss of sensation in the area supplied by the median nerve. The left radial pulse was decidedly smaller than that on the opposite side.

Sept. 13 to 23. Movement in biceps regained, but median anæsthesia was replaced now by painful hyperæsthesia.

Sept. 23. Axilla opened by an incision along its anterior border, and a small fragment of shell removed from the inner cord of the brachial plexus.

Oct. 11. Sensation practically normal.

Jan. 6, 1916. Patient was examined and found practically normal.

March 10. He returned to hospital complaining of aching pains in the shoulder. An oval-shaped swelling was discovered, measuring about one and a half inches by one inch, below the centre of the left clavicle (*Fig.* 110). An expansile pulsation synchronous with the cardiac systole could be felt in the swelling, but there was no thrill. A soft systolic bruit was heard over the swelling, and could be traced down the axilla to the middle of the arm.

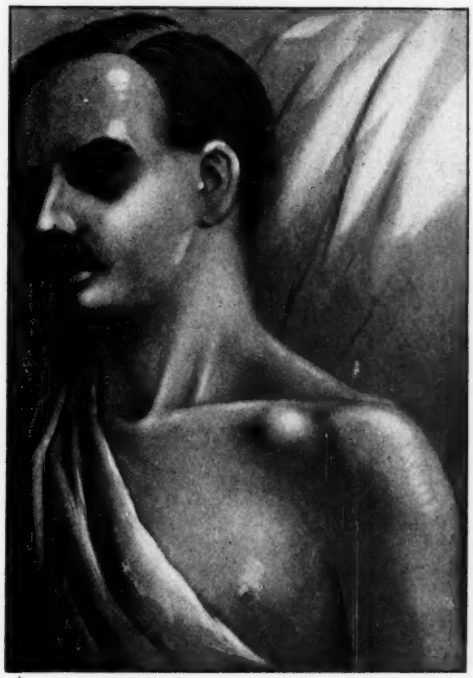

FIG. 110.—Appearance of the aneurysm before operation.

March 23.—In spite of complete rest the aneurysm has grown larger and its pulsation is more marked.

OPERATION. Incision over the clavicle, with exposure of the third part of the subclavian artery, which developed into a fusiform swelling beneath the clavicle. Pressure on the subclavian artery arrested pulsation in the aneurysm, which could be emptied on pressure. On removal of the pressure the sac rapidly filled without the artery being released. Temporary ligatures were placed round the subclavian artery. The axillary artery was exposed through an incision between the pectoral and deltoid muscles. The clavicular origin of the pectoralis major was divided. The axillary artery was traced to the lower part of the aneurysm, and temporarily ligatured. Traction on the axillary and subclavian ligatures stopped the pulsation in the aneurysm, but the sac remained tense, and though it could be emptied by pressure, it quickly filled again. The aneurysm was fully exposed, by dividing the clavicle, the subclavius muscle, and the costocoracoid membrane. The cords of the brachial plexus were carefully separated from the sac. The aneurysm was formed by a gradual enlargement of the subclavian

artery above, which led to a rounded sac beneath the clavicle as large as a hen's egg.

The temporary ligatures above and below the sac were now tied, and the sac was opened. After the clot had been turned out, free arterial bleeding occurred from a branch of the artery which entered the aneurysm. This bleeding was controlled by Kocher's forceps, which were left in position. The wound was closed after wiring the clavicle, and was drained by gauze packed

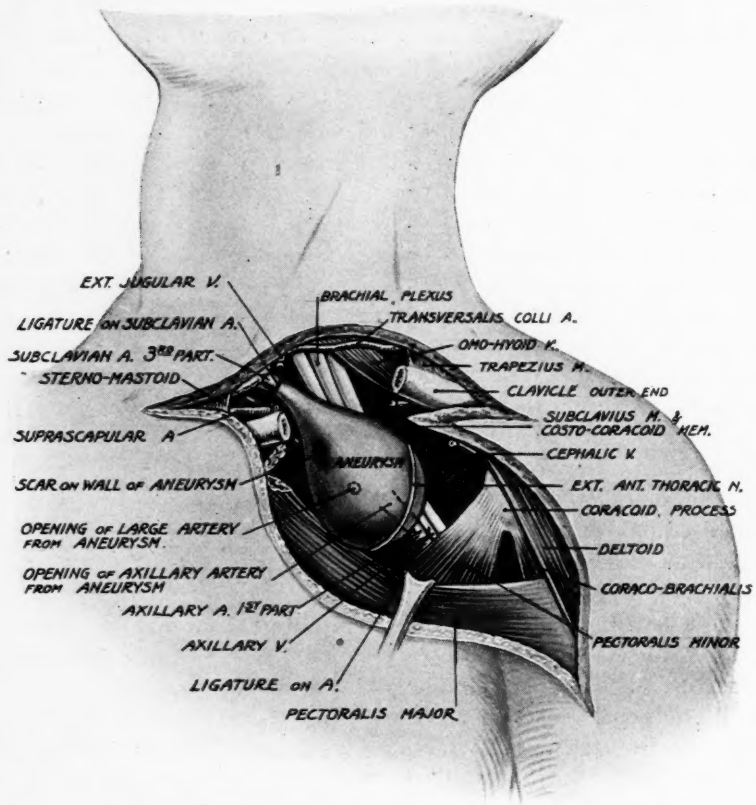

FIG. 111.—Diagram of the aneurysm as found at operation.

round the forceps. The forceps were removed five days later, and the recovery was uninterrupted, the radial pulse being present the day after the operation.

REMARKS.—It is remarkable that this aneurysm, which must have arisen from injury to the artery by the upper of the two shell-fragments, should not have become apparent until six months after the injury. I expected to find a sacculated aneurysm, but instead of this there was a large fusiform dilatation of the vessel quite unsuitable for any kind of reconstruction operation. The case is instructive also as showing the futility of a simple proximal ligature.

XVI.—THREE CASES FROM THE MILITARY HOSPITAL, DEVONPORT.

By C. HAMILTON WHITEFORD.

Case 1.—**Diffuse Infected Aneurysm from Wounds of the Left Brachial and Anastomotica Magna Arteries.**—[*Ref. No.* 111.]

On admission, the patient, who had been wounded by shrapnel in France, was found to have lacerated wounds on the inner and outer sides of the left arm, immediately above the elbow. The anterior surface of the lower part of the arm was occupied by a non-pulsating swelling the size of a fist. There was great œdema of the upper forearm, with absence of the radial pulse. Operation was performed for secondary hæmorrhage.

Operation, Sept. 23, 1914.—The inner wound was enlarged to four inches. Masses of foul-smelling clot were removed from a cavity the size of a goose egg, situated between the brachialis anticus muscle and the humerus, which was exposed in places. The bleeding points were the anastomotica magna artery and several veins. These were ligated. The brachial artery ceased to exist one inch above the elbow-joint, and did not bleed; its distal extremity was not seen. The inner wound was sutured. The outer wound was enlarged, and through this opening the cavity was swabbed with tincture of iodine, and then packed with gauze wrung out of a mixture of tincture of iodine one part, methylated spirit four parts. The hand and forearm were wrapped in cotton-wool, and fixed on a rectangular splint.

On the tenth day after the operation, half an ounce of thick pus was evacuated by an incision in the back of the wrist. Ten days later an abscess in the upper forearm was incised. On the sixtieth day all the wounds had healed. The arm and forearm were little more than skin and bone; the power of flexing the elbow was very slight, but there was a fair amount of power in the hand. Under prolonged massage all the muscles recovered, and the result was so useful an arm that the patient returned to duty.

Remarks.—The nerve trunks in the region of the elbow-joint were not seen during the operation, and had escaped serious injury, hence the good functional result.

Case 2.—**Diffuse Traumatic Aneurysm from Wound of the Left Superficial Femoral Artery.**—[*Ref. No.* 112.]

The patient came from the Dardanelles. On admission, scars of entry and exit of a bullet were seen in the centre of the left thigh; this was tense, blue, and œdematous, and double the size of its fellow; it did not pulsate. General wasting and anæmia were very marked.

Operation, Sept. 19, 1915.—The common femoral artery was controlled by digital pressure in the groin, and during the operation four pints of saline solution were injected into the right median basilic vein. An eight-inch incision was made on the antero-internal aspect of the upper and middle thigh, and two pints of blood-clot were evacuated. In the superficial femoral artery in Hunter's canal was an oval punched-out lateral wound, the long diameter of which measured half an inch. The opening was closed by lateral

suture, but this just failed to control the bleeding. The patient's condition, which had become precarious, prevented further attempts at suture, and the artery was divided between ligatures applied above and below the sutured area. The huge cavity, lined with partly organized clot, was packed with gauze wrung out of tincture of iodine and methylated spirit.

Gangrene of the œdematous leg ensued, and amputation was performed through the middle of the thigh. Diarrhœa, from which he had suffered in the Dardanelles, developed, and resisted all treatment. No amœbæ were found in the stools. A vaccine prepared from a bacillus found in the urine, and emetine hypodermically, proved of no avail. The patient, wasted to a skeleton, died six weeks after the first operation.

Remarks.—This anæmic and wasted patient had a vitality which was remarkable and, but for the recurrence of his diarrhœa, would have stood a fair chance of recovery. The stump, though mildly septic, partly healed, and did not appear sufficient to account for the diarrhœa, which was probably similar to that which has been so common among the troops in Gallipoli.

Case 3.—**Diffuse Traumatic Aneurysm from Wound of the Right Profunda Femoris Artery.**—[*Ref. No.* 113.]

This patient also came from the Dardanelles. On admission, the scar of a bullet wound was seen in the right thigh two inches below the centre of Poupart's ligament, and another scar on the inner side of the thigh four inches below the groin. Scarpa's triangle was occupied by a tense, non-pulsating tumour the size of a cocoanut. The patient was very anæmic. During the night preceding the operation the pain in the groin became worse and the tumour increased in size. This was attributed to a secondary hæmorrhage.

Operation, Sept. 20, 1915.—The common femoral artery was controlled by digital pressure in the groin, and during the operation four pints of saline solution, with half an ounce of brandy, were injected into the left median basilic vein. A six-inch incision in the line of the femoral artery was made from one inch below Poupart's ligament. Three handfuls of clot were evacuated, together with recent fluid blood. On relaxing the pressure in the groin, copious arterial bleeding came from the bottom of the upper part of the cavity. Considerable difficulty was experienced in exposing the bleeding point, which was ultimately located in the profunda artery, one and a half inches from its origin, and ligated.

An unfortunate accident was now found to have occurred. The edges of the incision in the skin and muscles had been held apart with tissue forceps, and on removing these it was found that a large artery (probably the superficial femoral displaced forwards by the mass of clot) had been punctured by the forceps. This artery bled freely, and had to be divided between ligatures. The cavity was treated as in the previous case.

During the twenty-four hours following operation, saline solution was administered per rectum. The circulation in the foot, after hesitating for a few days, became re-established. The cavity suppurated, but recovery slowly ensued.

REMARKS.—For *Cases* 2 *and* 3 the writer is indebted to Lieut. A. H. Walker, R.A.M.C., who assisted at the operations. In these examples of large cavities lined by adherent blood-clot, the condition of the patient, not to mention the probable presence of sepsis, usually contra-indicates prolongation of the operation by attempts at obliterating the cavity by sutures. In an anæmic patient, for whom intravenous saline infusion has been necessary, oozing often tends to be excessive; but this can be controlled by plugging the cavity with gauze wrung out of methylated spirit and iodine, as was done in the above cases.

XVII.—TWO CASES FROM THE READING WAR HOSPITAL.

BY CAPTAIN J. L. JOYCE, R.A.M.C. (T.C.)

A large number of examples of traumatic and arterio-venous aneurysm have been recorded in the medical journals during recent months. The following two cases have points of special interest and seem worth adding to those already published.

Case 1.—**Aneurysmal Varix of the Femoral Artery, with Secondary Hæmorrhage.**

Pte. W. B., age 26, was wounded in France on Sept. 28, 1915, and admitted to hospital on Oct. 8, 1915, with the following note: "On cutting down to extract a bullet, an aneurysm of the femoral was discovered—Bullet not found. Wound closed and drained."

ON ADMISSION.—On the inner side of the left thigh was a suppurating incision four inches long. There were four salmon-gut sutures still holding the upper part of the wound together. There was a large area of redness and œdema round the wound, and the skin looked tense and shiny. Pulsation and a well-marked thrill could be felt in the line of the femoral artery, and a loud bruit could be heard on auscultation. Pulsation in the left posterior tibial artery was weaker than in the right. The left leg and foot were not swollen. Towards the outer side of the posterior surface of the thigh was a small clean incision, under which could be seen by *x* rays a rifle bullet lying 1½ cm. deep.

The stitches were removed, and the suppurating wound at once gaped, exposing to view the sartorius muscle with pus welling up on both sides of it. The wound was treated by four-hourly irrigations with Dakin's hypochlorous solution and by hypochlorous fomentations. After a few days the swelling and redness of the thigh disappeared, and the wound looked much cleaner. There was no palpable swelling anywhere along the line of the femoral vessels, and no interference with the arterio-venous communication seemed indicated. The wound had closed after fourteen days, with the exception of a large sinus passing from its centre into the thigh under the inner edge of the sartorius.

On Oct. 29, three weeks after admission, there was a sudden severe secondary hæmorrhage from the sinus. A tourniquet was applied, and the patient taken to the operating room. The old incision was opened, and the

sartorius retracted inwards, exposing a suppurating cavity in the lower part of Hunter's canal. The artery was seen on the deep side of the cavity. On loosening the tourniquet, the bleeding was seen to come from a hole in the artery on its free side. As the wound was infected, no attempt was made to define the arterio-venous communication. A ligature was placed on the artery above and below the bleeding point. The tourniquet was removed and the hæmorrhage did not recur. The wound was left open, and a counter-incision made into the cavity from behind.

FIG. 112.—The free side of the artery, with the opening, and the cuff of tissues round its margin.

FIG. 113.—Shows the obliterated artery above the communication.

FIG. 114.—The femoral vein opened to show the communication between the two vessels. The unobliterated artery below the communication is visible.

The following notes describe briefly what took place after the operation :—

Oct. 30. There was no more bleeding. The toes of the left foot looked blue.

Nov. 2. The skin over the toes and distal third of the left foot was dry and shrivelled and discoloured. The wound in the thigh was cleaner.

Nov. 11. The whole foot was dried up and withered, and possessed no sensation. The gangrene extended two inches above the ankle. There was some slight œdema of the leg as far up as the knee. With the exception of two small sinuses, the wound in the thigh had healed.

Nov. 12. There was a slight hæmorrhage from one of the sinuses in the thigh after the patient had used the bed-pan. Calcium chloride was given in 5-grain doses.

Nov. 13–24. Slight hæmorrhage occurred on several occasions. The discharge of pus from the sinuses increased in amount. On Nov. 24 there was a further severe secondary hæmorrhage, which was checked by plugging the wound with gauze. The same evening the temperature ran up to 104°, and the pulse became very rapid.

Nov. 25. The left leg was amputated through the upper third of the thigh by unequal flaps, which were left unsutured, as pus was found in the inter-muscular planes at the site of the amputation.

AFTER-HISTORY.—The flaps suppurated freely for some days after the operation, and then became clean; but the patient sank, with septicæmic symptoms, and died on Dec. 23, with signs of septic infarcts in the left lung. Blood cultures on two occasions were negative, but a streptococcus was grown from the pus.

DESCRIPTION OF SPECIMEN (*Figs.* 112, 113, 114).—There was a large cavity under the sartorius muscle in the lower part of Hunter's canal. The artery and vein were dissected out *en bloc.*

In the side of the artery next the abscess cavity was a hole about one-eighth of an inch in diameter, and projecting from its margin was a cuff of fragile tissue with frilled edges. Above, the artery was converted into a fibrous cord for a distance of two inches, but its lumen was patent below, and the lower ligature tied round the artery at the first operation could not be found. The artery and vein were firmly adherent to each other, and embedded in a dense mass of fibrous tissue. The vein was opened, and the communication between the two vessels was found to be exactly opposite the hole in the free side of the artery. The vein was patent, but below the opening into the artery its lumen was partly filled with adherent blood-clot, and its endothelium was discoloured.

REMARKS.—The study of the specimen and the position of the entrance wound on the inner side of the thigh suggest that this case may be one of those uncommon instances where an aneurysmal varix has resulted from a perforation of both vessels from side to side. Surg.-Gen. Sir G. H. Makins* expresses his belief that, when this occurs, it " usually follows the spontaneous consolidation of a false aneurysmal sac on the free side of the artery." The frilled cuff of tissue round the opening on this side of the artery in the present instance may be the remains of a sac of this nature.

The case raises the question of the treatment of secondary hæmorrhage from the region of an aneurysmal varix of the femoral vessels. The parts were intentionally disturbed as little as possible at the first operation, on account of the sepsis. The artery was ligatured above and below the bleeding point, and this completely stopped the hæmorrhage for fourteen days. The communication between the two vessels was thought to be on the distal side of the lower ligature, as both thrill and hæmorrhage had ceased. The vein was not ligatured, in the hope that gangrene would then be avoided. Unfortunately the bleeding point was exactly opposite the arterio-venous communication, and the collateral circulation was so feeble that, although the vein remained patent, the foot became gangrenous very rapidly.

It is impossible to say whether the further hæmorrhage which took place after a fortnight was due to the lower ligature becoming loose; to an escape from the vein owing to the establishment of a more efficient collateral circulation; to the breaking down of a blood-clot; or to a combination of these factors. The patient's chance of recovery would have been greater had the amputation through the thigh been performed when the first hæmorrhage occurred. Surg.-Gen. Sir G. H. Makins, in his recent review of these cases,

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* BRITISH JOURNAL OF SURGERY, iii, No. 11, pp. 372 and 373.

remarks on the difficulty of finding the point of communication between the vessels, and this is enhanced in a suppurating wound complicated by secondary hæmorrhage. Under these circumstances, and remembering the likelihood of gangrene following an operation of local ligature, it is believed that in cases of secondary hæmorrhage from the region of an aneurysmal varix of the femoral vessels, amputation is the best treatment to adopt.—[*Ref. No.* 126.]

Case 2.—**Circumscribed Traumatic Aneurysm of the Brachial Artery.**

Pte. K., age 22, was admitted on Aug. 21, 1915, after being wounded in Gallipoli.

On Admission.—There was a healed entrance wound on the inner side of the left upper arm about an inch below the anterior axillary fold, and an unhealed exit wound on the posterior surface of the arm just below the posterior fold. Patient complained of burning pain in the left hand, which had been present from the time he was wounded.

The exit wound healed rapidly, and the man was transferred to an auxiliary hospital, where he soon began to notice loss of power in the left hand and forearm. He was re-admitted to the central hospital for further treatment on Nov. 18.

Fig. 115.

Fig. 116.

Figs. 115, 116.—Aneurysm of brachial artery. The false sac, showing four areas: From left to right these were in relation with (*a*) A large vein; (*b*) The ulnar nerve; (*c*) The median nerve; (*d*) Fibres of the coracobrachialis. Fig. 116 shows the sac opened.

On re-admission, he was found to have marked wasting of all the muscles of the left hand and the flexor muscles of the left forearm. The fingers were extended, and the power of flexion was very weak. Abduction and adduction of the fingers were impossible. Sensation to light touch was present everywhere on the hands and fingers, while pin-prick in the cutaneous area of the median nerve caused intense pain, and produced small scarlet spots which persisted for forty-eight hours. Elsewhere in the hand, pin-prick was normally felt. Over the fingers the skin was glossy and sweating, and in the palm of the hand was soft, flabby, and moist. Just below the anterior axillary fold, in the line of the brachial artery—slightly to the inner side of the healed entrance wound—was an oval swelling measuring two and a half by two inches. Expansile pulsation was present. There was no thrill, but a loud bruit was audible on auscultation. The pulsation and bruit were abolished by pressure on the subclavian artery, and the swelling was increased in size by pressure on the distal side of the brachial artery.

Operation, Nov. 22.—The artery was tied above and below the aneurysm,

which was then dissected out and removed. The relations of the aneurysm were as follows: To its outer side were some fibres of the coracobrachialis which were adherent to the aneurysm. To its inner side was a large, firmly adherent vein. On the anterior and outer surface the median nerve was spread out over the sac, and was adherent to the sac wall; after separation, the posterior surface of the median nerve was seen to be roughened and eroded. On the anterior and inner surface the ulnar nerve was tightly stretched over the sac, but was not adherent to it. Posteriorly there was a large vein, and further back condensed areolar tissue and the musculospiral nerve.

After-History.—On the evening of the operation the left hand was quite warm, and the radial pulse perceptible. The wound healed without trouble, and massage was begun at once. Eleven weeks later the muscles of the forearm and hand had recovered, and all movements of the hand and fingers could be performed. The patient still complained of pain in the area of the hand supplied by the median nerve. The skin was still glossy and sweating.

Remarks.—The specimen shows a false aneurysmal sac of the brachial artery (*Figs.* 115, 116). The bullet probably passed between the vessel and the median nerve, wounding both at the same time. This would explain the immediate onset of pain in the hand at the time of the injury, and the slowness of its disappearance compared with the later development of loss of power, and its rapid recovery after removal of the aneurysm.—[*Ref. No.* 127.]

XVIII.—SEVEN CASES FROM THE 4th NORTHERN GENERAL HOSPITAL, LINCOLN.

Case 1.—False Aneurysm of the Lower Third of the Brachial Artery.

Pte. D., age 22, was wounded by a rifle bullet on Sept. 25, 1915, and admitted to hospital on Oct. 1, with two small punctured wounds in the right upper arm. The entrance wound was two and a half inches above the elbow-joint to the outer side of the biceps. The exit was three inches above the internal condyle, inner border. There was marked extravasation of blood in the lower third of the upper arm, and decided pulsation was seen and felt above the bend of the elbow. The entire forearm was swollen, with numbness of the fingers and hand. No pulse was to be felt at the wrist.

Operation, Oct. 4.—The brachial artery was exposed above the false sac and tied; and also below at the bend of the elbow, being tied just above the bifurcation. The sac was opened and blood-clot turned out; this was followed by rather free bleeding, and the wound was packed with gauze.

Oct. 9. The pulse was now felt at the wrist. On removing the plugging the wound bled profusely. An anæsthetic was given in the afternoon, and the brachial artery was then found to have a vertical slit one inch long, and opening into the slit portion was a large vessel, the anastomotica magna. This was ligatured.

Oct. 19. The patient complained of great pain in the hand, and the area of skin supplied by the median nerve was hypersensitive. The grip was feeble. This gradually improved.—[*Ref. No.* 132.]

Case 2.—**Arterio-venous Aneurysm of the Common Femoral Artery.**

Pte. J. B., age 31, was wounded by a rifle bullet on Oct. 1, 1915, and admitted to hospital on Oct. 11. He had a small punctured wound, covered by a scab, in the right thigh, two inches below the anterior superior spine. There was slight discoloration of the right groin, with some swelling immediately below Poupart's ligament; a very marked thrill could be felt over the swelling, and a decided venous hum could be heard. There was no swelling or blueness of the leg, and pulsation was felt in the anterior and posterior tibial arteries. There was no distention of the veins of the leg.

An *x*-ray examination showed a rifle bullet lying on the pubic arch, apparently immediately below the vein.

Operation, Oct. 16.—An incision was made over the common femoral artery, which was slightly dilated. The vein was not seen. A ligature was placed round the artery just below Poupart's ligament, and another below the dilatation. Above the profunda femoris, a small incision was made on the inner side of the vein, and the bullet felt. On attempting to extract it with forceps a gush of venous blood followed, so the bullet was left and the incision plugged. No bad symptoms followed. The foot remained warm and a good colour. There were never any signs of gangrene, nor was there any recurrence of venous bleeding.—[*Ref. No.* 133.]

Case 3.—**False Aneurysm of the Tibial Artery.**

J. M., age 25, was admitted on March 21, 1915. On March 14 he had been wounded by a rifle bullet which passed through his right calf. The wounds had been incised; there was one three-inch wound on the inner side of the leg two and a half inches below the knee, and another on the outer side in the middle third. The leg was swollen and painful. A blowing systolic murmur could be detected over the lower part of the popliteal space, most clearly heard over the origin of the anterior tibial artery and around the outer wound. There was no pulsating swelling to be seen or felt. The anterior and posterior tibial arteries could be felt beating at the ankle.

On March 24 a consultation with other members of the staff was held; the condition was diagnosed as a wound of one of the arteries in the lower part of the popliteal space, and an operation was decided on.

Operation.—This was performed by Major Watkins, under chloroform anæsthesia. A tourniquet was applied to the thigh. A long incision was made in the middle line of the back of the leg, exposing the lower two-thirds of the popliteal space and the upper part of the calf. The heads of the gastrocnemius muscles were retracted. All the tissues were black and infiltrated with blood, but no distinct aneurysmal cavity could be made out. The popliteal nerve was drawn gently aside so as to expose the popliteal vein, which was followed down to the lower edge of the popliteus muscle. All the vessels were matted together and difficult to separate, and it was found necessary to ligature the vein in order to be able to reach the seat of the trouble. When this had been done, it was clearly seen that the bullet had passed across the leg just below the level of the origin of the anterior and posterior tibial arteries, wounding the posterior tibial and peroneal arteries as they lay close together at their origin. The anterior tibial artery was also wounded, but it was not

quite certain if the wound had been inflicted during the difficult dissection of the vessels. The anterior and posterior tibial and peroneal arteries and veins all had to be ligatured. The wound was sutured, and a drainage tube left, going down into the popliteal space.

The circulation of the limb was well maintained throughout the convalescence; no sign of gangrene was at any time manifested. The patient complained of great pain in the foot for four or five months, which caused him to walk with a slight limp. On the fourth day after operation the anterior tibial artery was felt to be beating faintly on the dorsum of the foot. There was free discharge of pus from the wound after the first five days (up to this there had been a blood-stained serum).

By the end of August the wound had healed, and except for occasional pain in the foot the patient was quite well, and was discharged to light duty on Oct. 23, 1915.—[*Ref. No.* 134.]

Case 4.—**False Aneurysm of the Ulnar Artery.**

Rifleman C. was admitted to hospital on May 17. He had been wounded by a rifle bullet in the left forearm on May 9.

On admission, he had two wounds in the left forearm; the entrance wound was situated in the middle of the flexor aspect, and the exit was at the same level on the ulnar aspect. Both wounds were small and clean-cut. His forearm was swollen, and he was unable to use the flexor muscles; sensation on the ulnar side of the hand was impaired, but not lost.

On May 18 there was some hæmorrhage from the ulnar wound; a tourniquet was applied temporarily, and the wound re-dressed and bandaged lightly. On the evening of May 19 hæmorrhage recurred. On May 21 there was a localized pulsating swelling, at the summit of which was the ulnar wound. The radial pulse was present, but there was no ulnar pulse at the wrist; a thrill was present over the swelling.

Operation, May 21, by Colonel Carline.—At 8 p.m. the patient was anæsthetized with chloroform, and an incision made over the swelling rather to its ulnar side. A large cavity filled with clot was opened up between the superficial and deep layers of the flexor muscles; there was free hæmorrhage when the tourniquet was slackened. Attempts to see and secure the bleeding point failed; apparently the bleeding came from the under aspect of the flexor carpi ulnaris, which was the roof of the sac. Another incision was then made parallel to the first, but to the radial side of the sac; attempts to secure the bleeding point failed in this case also. An incision was then made in the antecubital fossa over the site of the brachial artery. An artery was found beneath the bicipital fascia having the course and relations of the brachial artery, but it appeared to be much smaller than normal; this vessel was ligatured; free hæmorrhage occurred, however, on releasing the tourniquet. A fourth incision was then made along the inner border of the biceps in the upper arm, and the brachial artery was exposed and ligatured; the vessel here was at least three times the size of the vessel exposed in the antecubital fossa (which was thought to be the ulnar coming off abnormally high up). The hæmorrhage was much diminished, but was still very free. The cavity was then plugged with gauze, and the patient taken back to the ward.

On May 23 the plug was removed, and no further hæmorrhage occurred. The plug was lightly replaced. The patient's temperature was 102°. On May 25 there was a good deal of suppuration in all the wounds. These were all healed by June 4. The patient could not fully extend his forearm owing to the antecubital scar, and could not flex his wrist or fingers.

On July 22 the patient returned from a convalescent home; he could only extend his forearm to 120°, he could not extend completely his ring and little fingers, and he could not abduct or adduct his fingers. There was loss of epicritic and protopathic sensibility over the ulnar side of the ring finger and the whole of the little finger. Reaction of degeneration was present in the interossei, in the muscles of the hypothenar eminence, and in the adductor transversus pollicis. There was some contracture of the flexors of the forearm, and wasting of the muscles of the thenar and hypothenar eminences. Patient refused further operative treatment, and was treated with chlorine cataphoresis. —[*Ref. No.* 135.]

Case 5.—**False Aneurysm in Hunter's Canal.**

Lieut. N., age 19, was hit on Oct. 13, 1915, by a rifle bullet which passed through the middle of the left thigh. He was in hospital in France thirty hours, and was then transferred to England, where he stayed in hospital from Oct. 16 to Nov. 10. He lost a good deal of blood at the time he was wounded. There was no hæmorrhage while in hospital. The course of the bullet was from front to back about the line of the upper end of Hunter's canal. At first there was some discharge of pus from both wounds. They were both healed up by Nov. 8, when he was discharged on leave for a month, and went home. On Nov. 12 he had much pain in the thigh, which began to swell, and pulsation was noticed.

He was admitted to the general hospital on Nov. 15, with a diagnosis of traumatic aneurysm of the left femoral artery. There was great swelling of the thigh, and arterial pulsation round the entrance wound.

Operation, Nov. 16, by Colonel Carline.—The femoral artery was tied above and below the aneurysm; but owing to the presence of severe shock it was thought inadvisable to deal with the large effusion of blood in the thigh. After operation the pulse was thready, and about 160. In the evening he began to recover from shock.

He steadily improved during the next fortnight; there was no recurrence of bleeding or pulsation, the extravasated blood was rapidly being absorbed, and the wound was clean and healing. Some serum was exuded daily. The circulation in his leg was very good.

Dec. 1. Wound healing rapidly; swelling of the leg much less.

Dec. 20. Practically all extravasated blood absorbed; wound nearly healed.

Dec. 24. Wound healed; very little swelling of leg; circulation in leg good.

Dec. 28. Allowed up on crutches.

Jan. 6, 1916. Can walk with slight stiffness. General health good.

Jan. 8. Went home on furlough.—[*Ref. No.* 136.]

Case 6.—**Aneurysmal Varix of the Profunda Femoris Vessels near their Origin.**

Pte. T. H., age 39, was struck by a rifle bullet in the left groin on April 6, 1915, and was taken to a base hospital, where he remained seven days.

On admission to the general hospital on April 22, the wound of entrance was found clean and dry, the size of a pea; no exit wound. Arterial pulsation was seen and felt at the entrance wound and for half an inch around, a venous thrill could be felt down the internal saphenous vein, and an arterio-venous drumming heard over the vein as far down as the knee. Arterial pulsation at the malleoli was equal. There was no nerve lesion.

April 29. The venous thrill was less marked down the leg, but more so in an upward direction. There was little or no change for the next three weeks.

Operation, May 21, by Colonel Carline.—Under chloroform the femoral artery was exposed, and found rather small. It was tied, but although this diminished the thrill, it did not stop it.

Next day the circulation in the leg was poor. In three weeks the circulation was much better, and the thrill less marked. There was very little change during the next three months; he was allowed up two months after operation.

Sept. 11. There was still a loud murmur and forcible thrill for several inches below the cicatrix. The foot was swollen and cold, and turned bluish when dependent. He was himself set to compress the vein at the spot where blood appeared to pass from the artery to the vein, and to obliterate the thrill; this he did for half an hour at a time two or three times a day during October and November. By the end of November the circulation in the leg was decidedly improved, but the thrill and murmur were still very pronounced.

Operation, Dec. 9, by Colonel Carline.—The vessels in the upper part of Scarpa's triangle were exposed, and the profunda femoris was tied. This obliterated the thrill. The main trunk continued to pulsate. The wound was closed and the leg put up in wool.

Dec. 10 and 11. The leg was warm. The patient had "stinging in leg and toes," which were warm.

Dec. 14. A loud bruit was heard over the vessels, but no thrill was felt.

Dec. 20. The wound was healed.

Dec. 28. A slight thrill was felt for about the length (vertical) of an inch over the wound.

Jan. 6, 1916. Patient got up. Circulation in the leg and foot was very fair. The thrill was very slight.

Jan. 19. For about one and a half inches over the superficial femoral there was a marked thrill, but no swelling.

Jan. 30. The patient was examined by the Medical Board, and discharged. There was no evidence of aneurysm except the thrill. He could walk well, and the circulation in the foot and leg was good.—[*Ref. No.* 137.]

Case 7.—**Popliteal Aneurysm.**

Cpl. P., age 32, was admitted on Oct. 4, 1915, suffering from a bullet wound, received Sept. 27, through the lower third of the right thigh on the posterior surface.

In the popliteal space there was a marked pulsating swelling, which extended well above the middle of the thigh on the posterior surface. The pulsation was expansile, a thrill was present, and a loud bruit was heard with the stethoscope. There was no pulsation to be felt in the posterior tibial or dorsalis pedis. There was defective sensation over the inner side of the dorsum of the foot, and considerable pain in the thigh.

Operation, Oct. 5, by Major Watkins.—A tourniquet was applied to the limb a little below the groin. A vertical incision was then made over the swelling, and a large quantity of clotted blood removed. It was found that the bullet had passed across the artery and vein, wounding both. Both vessels were tied above and below, after some difficulty due to the macerated condition of the tissue. A small drainage tube was inserted into the lower part of the wound.

On the following day the patient felt well, and was free from pain; the leg was warm, and the capillary circulation good; but the knee was flexed almost to a right angle. The wound healed by first intention.

Oct. 19. The knee was still flexed. Extension was applied, and the leg gradually straightened. By Dec. 3 the patient could use his leg without any inconvenience.—[*Ref. No.* 138.]

THE SURGICAL ANATOMY OF THE SYNOVIAL MEMBRANE OF THE KNEE-JOINT.

By Col. ANDREW FULLERTON, C.M.G., A.M.S.(T.)

One of the most anxious of the various problems that present themselves to the surgeon dealing with wounds in war is that of injuries involving the knee-joint. An apparently trivial penetrating wound may result in a stiff joint, amputation of the limb, or even death, notwithstanding great care and, in some cases, vigorous and radical treatment.

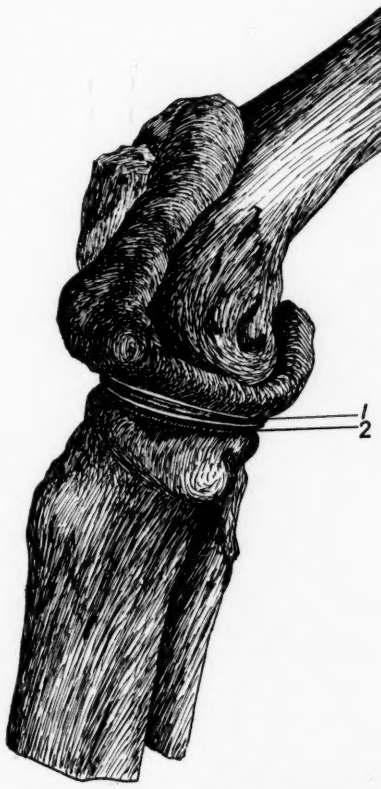


Fig. 117.—Internal view of right knee-joint, showing distended synovial membrane. (1) Internal semilunar cartilage; (2) Synovial membrane below cartilage.

Fig. 118.—External view of right knee-joint, showing distended synovial membrane. (In this case the cavity communicates with the superior tibiofibular articulation.) (1) External semilunar cartilage.

A movable joint after an infected wound of the knee is something to be proud of. The reason for this is not far to seek. The knee-joint has the largest and most complex synovial membrane in the body. Its size is not a matter of much consequence, except that a large surface is exposed for

absorption of bacterial poisons, should infection occur. It is the complexity of the joint that renders treatment so difficult. Diverticula, folds, recesses, and communications with bursæ, render it impossible to drain thoroughly; and irrigation, unless perhaps by a powerful force-pump, is quite inadequate to reach and wash out the various cul-de-sacs connected with the main cavity.

The question of foreign bodies in the joint is another problem. Their exact location and the best methods of approach require skilled *x*-ray work, and a knowledge of applied anatomy. Since I have been with the forces in France, I have found good stereoscopic *x*-ray pictures, studied in conjunction with drawings from sections hardened in formalin kindly made for me by Prof. Symington, of Belfast, of inestimable value. In addition, I have had many opportunities of examining fresh specimens of healthy knee-joints when post-mortems have had to be made for other conditions.

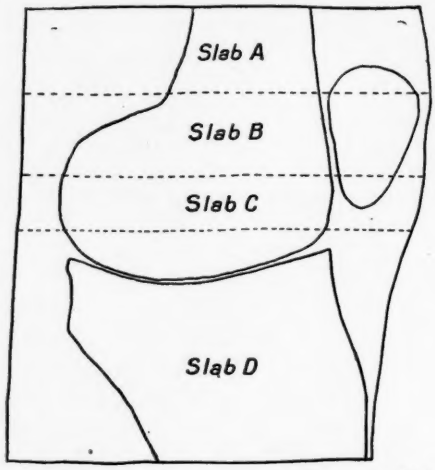


FIG. 119.—Key figure showing sagittal section of left knee through the inner condyle of femur.

I have been asked by some of the officers in my area, who have seen these drawings, to publish them for more general use. I have added to these an *x*-ray photograph kindly supplied by Lt.-Col. Robert Jones, of Liverpool, showing a joint inflated with oxygen, and also photographs showing joints injected with bismuth. The object of this paper is to illustrate the more important details of the synovial membrane from a surgical point of view, and to supply the shortest possible description compatible with clearness.

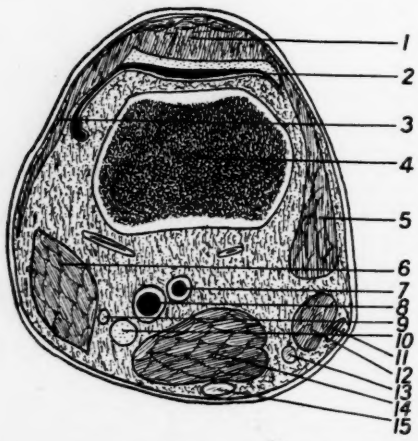


FIG. 120.—Horizontal section through knee-joint, dividing femur but passing above patella, viewed from above (see *Fig.* 119, *Slab A*). (1) Quadriceps muscle; (2) Joint cavity; (3) Fascia lata; (4) Femur; (5) Vastus internus; (6) Biceps muscle; (7) Popliteal artery; (8) Popliteal vein; (9) Common peroneal nerve; (10) Tibial nerve; (11) Great saphenous vein; (12) Sartorius muscle; (13) Gracilis muscle; (14) Semimembranosus muscle; (15) Semitendinosus muscle.

The articulation is composed of three parts, two femoro-tibial and a patellar (*Figs.* 124, 125). In some animals there are three separate synovial membranes. The arrangement in the human subject indicates its composite

nature. The cruciate ligaments are the lateral ligaments of the femoro-tibial joints (*Fig.* 124). Thus, the external condyle is held in its position on the superior articular surface of the tibia by the external lateral ligaments (fibular collateral) externally, and the anterior cruciate ligament, which repre-

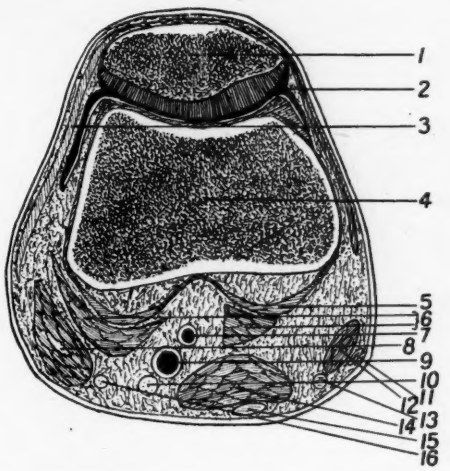


FIG. 121.—Horizontal section of knee-joint, dividing the femur and patella, viewed from above (see *Fig.* 119, *Slab B*). (1) Patella; (2) Joint cavity; (3) Fascia lata; (4) Femur; (5) Oblique popliteal ligament; (6) Gastrocnemius muscle; (7) Popliteal artery; (8) Biceps muscle; (9) Popliteal vein; (10) Tibial nerve; (11) Great saphenous vein; (12) Sartorius muscle; (13) Gracilis muscle; (14) Semimembranosus muscle; (15) Semitendinosus muscle; (16) Common peroneal nerve.

sents an internal ligament, internally. Similarly, the internal condyle is held in position by the internal lateral ligament (tibial collateral) internally, and the posterior cruciate ligament, which represents an external lateral ligament, externally. The cruciate ligaments, which cross each other like the letter X, divide the intercondylar fossa into two lateral recesses, into which, as we shall see, pockets of synovial membrane extend (*Figs.* 122, 124).

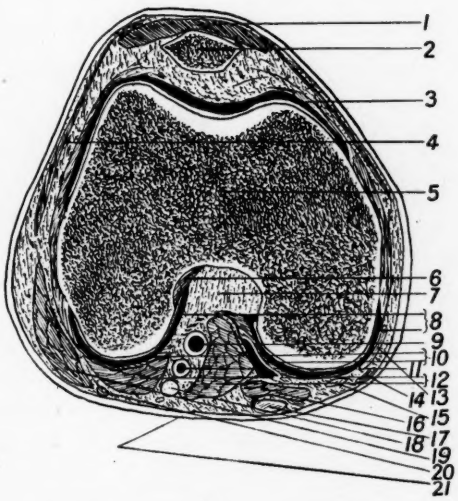


FIG. 122.—Horizontal section of knee-joint, dividing femur and the lower end of the patella, viewed from above (see *Fig.* 119, *Slab C*). (1) Patellar ligament; (2) Patella; (3) Joint cavity; (4) Fascia lata; (5) Femur; (6) Anterior cruciate ligament; (7) Posterior cruciate ligament; (8) Joint cavity; (9) Popliteal artery; (10) Oblique popliteal ligament; (11) Popliteal vein; (12) Gastrocnemius muscle; (13) Sartorius muscle; (14) Great saphenous vein; (15) Gracilis muscle; (16) Semimembranosus muscle; (17) Semitendinosus muscle; (18) Tibial nerve; (19) Biceps muscle; (20) Common peroneal nerve; (21) Bursa under semimembranosus and gastrocnemius.

The infrapatellar pad of fat (*Figs.* 123, 124, 125) further tends to subdivide the joint into its component parts. It consists of a wedge-shaped central portion (*Fig.* 125) which extends backwards and upwards to the intercondyloid fossa, and two lateral wings which extend along the lateral borders

of the lower part of the patella. Covered by synovial membrane, the central portion is attached above (proximally) to the anterior margin of the inter-

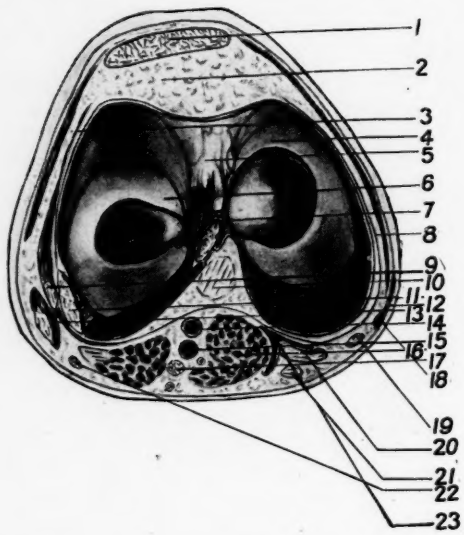
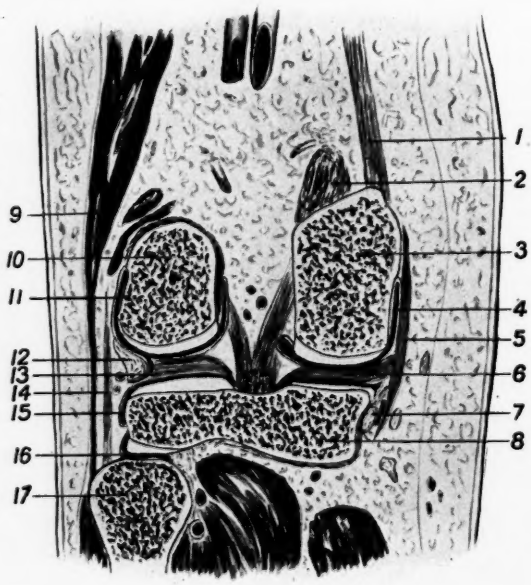


FIG. 123.—Horizontal section through knee-joint, dividing the condyles of femur and ligamentum patellæ, viewed from above (see *Fig.* 119, *Slab D*). The lower end of femur was removed to show the synovial cavity, cruciate ligaments, and semilunar fibrocartilages. (1) Patellar ligament; (2) Infrapatellar fat; (3) Capsule of joint; (4) Internal semilunar cartilage; (5) Ligamentum mucosum; (6) External semilunar cartilage; (7) Anterior cruciate ligament; (8) Capsule of joint; (9) External lateral ligament; (10) Posterior cruciate ligament; (11) Popliteus muscle; (12) Sartorius muscle; (13) Biceps muscle; (14) Popliteal artery; (15) Popliteal vein; (16) Gastrocnemius muscle; (17) Tibial nerve; (18) Great saphenous vein; (19) Gracilis muscle; (20) Semimembranosus muscle; (21) Semitendinosus muscle; (22) Common peroneal nerve; (23) Bursa under semimembranosus and gastrocnemius.

condyloid fossa. It is known as the ligamentum mucosum (patellar synovial fold) (*Figs.* 123, 131). The lateral extensions, similarly invested by synovial membrane, form the ligamenta alaria (plicæ alares). These ligaments (more

FIG. 124.—Transverse section through left knee and tibiofibular joints, viewed from behind. The femur was divided through the posterior part of its condyles, and the cruciate ligaments cut in the intercondyloid fossa. (1) Adductor magnus; (2) Inner head of gastrocnemius muscle; (3) Inner condyle; (4) Synovial cavity; (5) Internal lateral ligament; (6) Internal semilunar cartilage; (7) Semimembranosus muscle; (8) Tibia; (9) Biceps muscle; (10) External condyle; (11) Synovial cavity; (12) Popliteus tendon; (13) External semilunar cartilage; (14) External lateral ligament; (15) Synovial cavity; (16) Superior tibiofibular joint; (17) Head of fibula.



properly called folds) form a pad which fills up the irregular space between the patella, femoral condyles, and tibia (*Fig.* 123).

The semilunar cartilages (menisci) are shown in *Figs.* 123 and 124, and

their wedge-shaped appearance in section is well shown in *Figs.* 126 and 127, in which the parts are represented as separated somewhat, to show how the synovial membrane invests the upper and under surfaces and free borders.

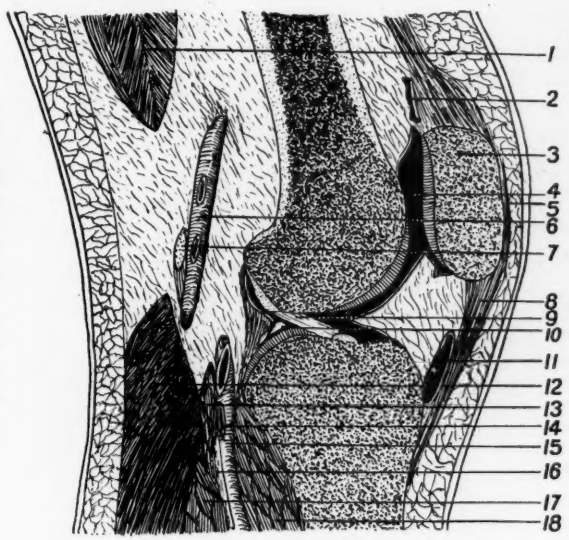


FIG. 125.—Vertical anteroposterior section, approximately through middle of knee-joint, lateral view. (1) Semimembranosus muscle; (2) Suprapatellar bursa; (3) Patella; (4) Joint cavity; (5) Prepatellar bursa; (6) Popliteal vein; (7) Peroneal nerve; (8) Patellar ligament; (9) Anterior cruciate ligament; (10) Posterior cruciate ligament; (11) Bursa over tubercle of tibia; (12) Gastrocnemius muscle; (13) Plantaris muscle; (14, 15) Popliteal vessels; (16) Tibial nerve; (17) Soleus muscle; (18) Popliteus muscle.

It should be remembered that, while the internal lateral ligament is adherent to the internal semilunar cartilage (medial meniscus) at its convex border, the external lateral ligament is separated from the external semilunar cartilage (lateral meniscus) by the tendon of the popliteus (*Figs.* 123, 124,

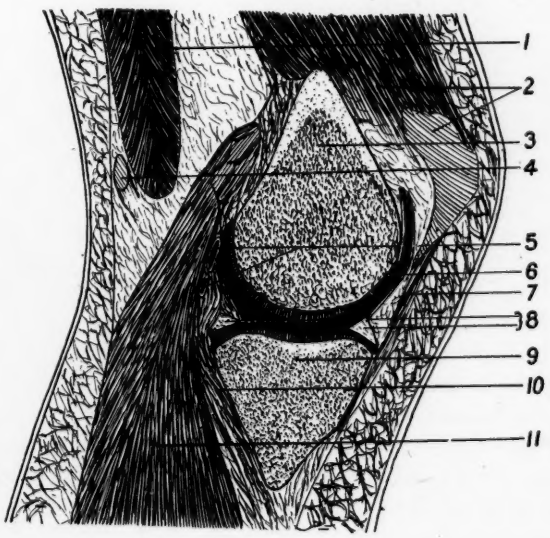


FIG. 126.—Vertical anteroposterior section of *right* knee internal to and 1·8 cm. from section *Fig.* 125, lateral view. (1) Semimembranosus muscle; (2) Quadriceps muscle; (3) Inner condyle of femur; (4) Tendon of semitendinosus muscle; (5) Bursa under gastrocnemius; (6) Cavity of joint; (7) Patellar ligament; (8) Internal semilunar cartilage; (9) Tibia; (10) Insertion of semimembranosus muscle; (11) Inner head of gastrocnemius muscle.

127), which, covered by a pouch-like prolongation of synovial membrane, is prolonged backwards and downwards, and grooves the outer convex border of the meniscus. This cartilage has, therefore, a covering of synovial mem-

brane on its outer convex border for part of its extent (*Figs.* 123, 124, 127 ; see also *Figs.* 129, 130).

The capsule of the knee-joint, together with the ligaments, tendons, and fascia which strengthen it, forms a complete investment for the joint, except at those places where communications with bursæ exist. It is very thin above the patella, where it is represented merely by the layer of synovial membrane which invests the under surface of the quadriceps muscle and is reflected on to the femur (*Fig.* 131). Here pus, distending the joint, may break through and burrow in the fascial planes of the thigh. In this connection, the possibility of the presence of Baker's cysts, which are hernial protrusions of the synovial membrane through defects in the capsule, ought to be borne in mind. These might, of course, become pockets of pus in septic infection of the joint, and complicate the treatment.

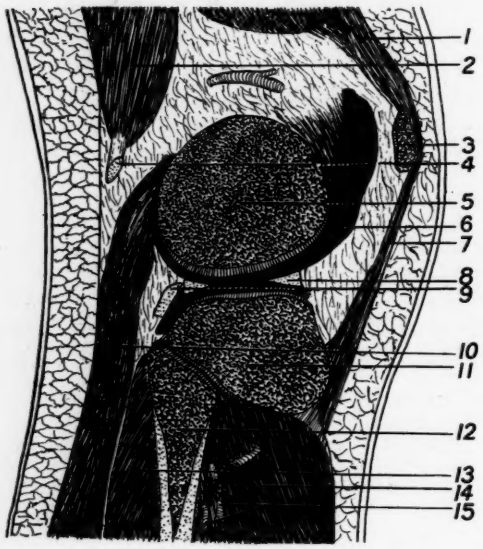


FIG. 127.—Vertical anteroposterior section of *right* knee, external to and 1·8 cm. from section *Fig.* 125. Lateral view. (1) Quadriceps muscle ; (2) Biceps muscle ; (3) Patella ; (4) Peroneal nerve ; (5) Femur ; (6) Joint cavity ; (7) Patellar ligament ; (8) External semilunar cartilage ; (9) Tendon of popliteus ; (10) Gastrocnemius muscle ; (11) Tibia ; (12) Fibula ; (13) Soleus muscle ; (14) Tibialis anticus muscle ; (15) Anterior tibial vessels.

The joint cavity is bounded by the articular cartilage and synovial membrane. The articular cartilage forms a firm, unyielding, non-vascular wall, whereas the synovial membrane, as a rule, is thin, readily displaced, and vascular, except over the semilunar cartilages, where it becomes very thin and firmly adherent. In addition to lining the capsular ligament, it covers the non-articular portions of the bones within the joint (*Fig.* 124), and various pads of fat. The joint cavity not only extends between the articular ends of the bones, but into numerous extensions of the synovial membrane. Thus, a pouch is pushed up under the quadriceps, and invests this muscle on its under surface and the femur for a distance of about an inch above the upper border of the patella (*Fig.* 131 ; see also *Figs.* 117, 118, 119). In *Figs.* 129 and 130 the joint has been over-distended with bismuth emulsion to show the arrangement of the cavity and its diverticula. In *Fig.* 125 its vertical extent is less than normal. This is due to the hardening process in the specimen from which the drawing was made. The protrusion communicates

with a bursa which extends for about another inch, by an opening which may be quite small, but is generally so large that the sacs are practically continuous, as shown in *Figs.* 129 and 130. The lateral extent of this upward protrusion is represented in *Figs.* 120, 121, 122, from slabs cut at the levels shown in the key (*Fig.* 119; see also *Figs.* 117, 118, 129, 130).

It will be apparent that a penetrating wound involving the anterior third of the circumference of the thigh within two inches of the upper margin of the patella or the condylar surface of the femur, is almost certain to be a wound of the joint, except in those rare cases in which the suprapatellar bursa does not communicate with the cul-de-sac from the joint. We have lately dissected a joint in which the suprapatellar bursa was filled with pus, but did not communicate with the joint. It is important to remember that occasionally the opening between these two cavities is quite small, and that movement may pump infective matter from the one to the other, an accident which might have been avoided by immobilization on a splint. In the kneeling position the cul-de-sac is drawn down with the patella, and may thus escape injury.

FIG. 128.—Joint injected with oxygen, anteroposterior view.

The synovial membrane which extends from the margin of the articular surface of the patella (*Fig.* 131), is continued on to the infrapatellar fat forming the ligamentum mucosum and the ligamenta alaria, as before described (*Figs.* 123, 125).

Note the arrangement in *Figs.* 117, 118, 129, 130, in which the joint has been distended. In the non-distended or normal state it will be seen that a missile can traverse the infrapatellar region, and even project a considerable distance backwards towards the joint, without actually involving the latter (*Fig.* 125).

It is important to remember that there is a bursa between the ligamentum patellæ and the tubercle of the tibia, which must not be mistaken for the joint itself. In *Fig.* 125 I have made an addition to the original drawing, showing the position of the bursa. A knowledge of the anatomy of this angle may enable a careful operator to remove a missile lodged there without opening into the knee-joint.

In the distended joint (*Figs.* 117, 118, 129), the relations of the structures in this angle are much altered. The synovial membrane is reflected on to the condyles of the femur and the tuberosities of the tibia as far as the articular cartilage, and is then as it were pushed into the intercondyloid fossa, lining it and its contained fat, and partially investing the cruciate ligaments (*Figs.* 123, 124, 125). In this way two recesses are formed, one on either side of the cruciate ligaments as they pass up from the non-articular surface between the facets on the upper (proximal) surface of the tibia to the intercondyloid fossa. These recesses are partially shown in *Figs.* 122, 123, 125.

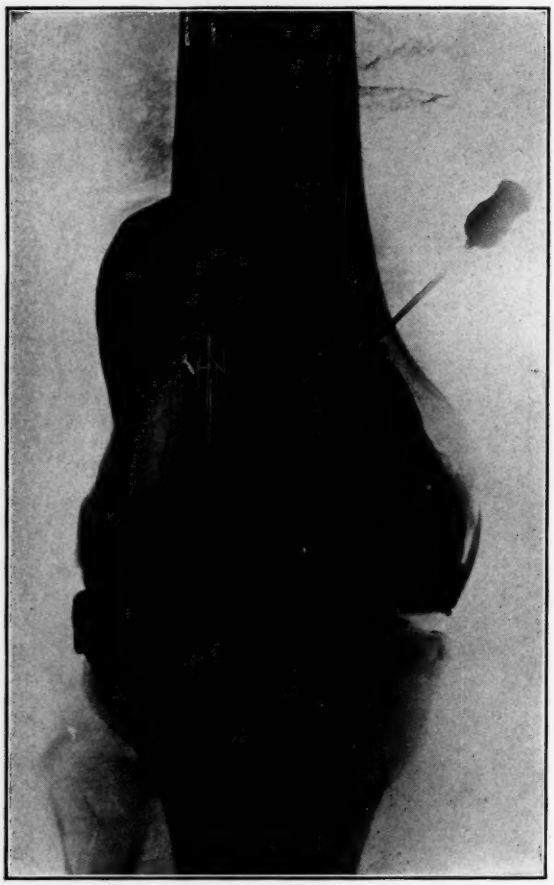


FIG. 129.—Joint injected with bismuth, anteroposterior view.

The cruciate ligaments form a septum dividing the synovial pouch in the intercondyloid notch into two cavities, in either of which a foreign body may lodge (*Fig.* 124). Pus is also likely to accumulate here, and in bad septic cases can only be efficiently dealt with by acute flexion after division of the lateral and cruciate ligaments, and removal of the semilunar cartilages. The posterior cruciate ligament (*Figs.* 122, 123) is devoid of synovial membrane at its posterior aspect, where it is connected with the posterior ligament of the knee-joint. Missiles may be lodged in this cruciate ligament, and yet be entirely outside the joint, and capable of being reached by an incision on the inner side of the popliteal vessels (*Figs.* 122, 123)—always remembering the presence of the bursa in that situation, which frequently communicates with the joint.

The synovial pouches which invest the condyles of the femur are well shown in cross section in *Fig.* 122, and in vertical section in *Figs.* 124, 125, and 126. Referring to *Fig.* 122, it will be seen that at this level there appear to be three pouches—two condylar and one behind the patella. Compare this figure with *Figs.* 117 and 118, in which the synovial membrane has been distended, for an explanation of the appearances seen. The synovial pouch is prolonged up behind each condyle to invest the cartilaginous surfaces, the whole sac, as seen laterally,

resembling the letter J. The synovial membrane is reflected from the cartilaginous surfaces of the tibia to invest the semilunar cartilages, as shown in *Figs.* 125 and 126.

In *Fig.* 127 the joint has been distended with oxygen, and the potential pockets, especially those between the cartilages and the tibia, are well shown. Compare also *Figs.* 128 and 129. On the outer side the tendon of the popliteus muscle (*Figs.* 123, 124, 127) receives a finger-shaped diverticulum of synovial membrane, which partially invests it and generally accompanies it as far as the tibio-fibular articulation, occasionally communicating with

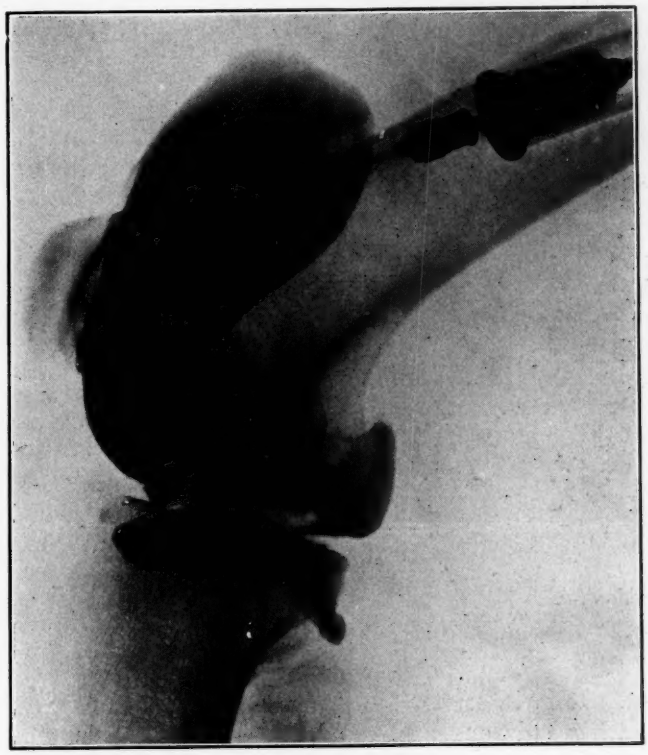


FIG. 130.—Joint injected by bismuth, lateral view. Note extension along popliteus tendon.

the latter (*Fig.* 127). This process of synovial membrane separates the tendon from the posterior part of the external surface of the external semilunar cartilage, and from the tibia (see *Figs.* 124, 127, 130). It is a source of serious danger in an infected joint, as pus frequently tracks along it, and breaks through to form an abscess in the ham or calf. This diverticulum we have found involved in almost every case in which amputation has been performed for a badly infected joint. It will be seen from the foregoing description that the external semilunar cartilage is covered, for part of its extent on the outer surface, by synovial membrane (*Figs.* 124 and 130), thus differing from the internal cartilage (*Figs.* 124 and 129).

Bursæ.—There are many bursæ in the neighbourhood of the knee, but only those that are likely to communicate with the joint need detain us here. The suprapatellar bursa has already been mentioned. A large and important bursa is that between the inner head of the gastrocnemius and the internal condyle of the femur. This bursa sends a communication between the tendons of the gastrocnemius and semimembranosus, and frequently communicates with the joint. It is shown in *Figs.* 123 and 125, and I have added it to the original drawing in *Fig.* 122. We have found that this bursa frequently shares in the infection of the joint. Movement is liable to pump infective matter into it from the joint, hence the necessity for absolute rest by fixation on a

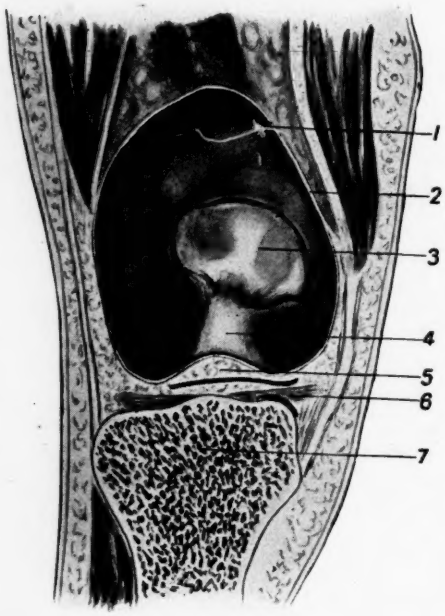


FIG. 131.—Transverse vertical section of knee-joint, viewed from behind. The femur has been removed to show the anterior portion of the cavity of the knee-joint with articular surface of patella. (1) Suprapatellar pouch; (2) Cut edge of synovial membrane; (3) Patella; (4) Ligamentum mucosum; (5) Infrapatellar pad; (6) Internal semilunar cartilage; (7) Tibia.

suitable splint. It is interesting to remember from one's experience of civil surgery that, when enlarged and tense, this bursa is easily emptied into the joint during flexion, while in the extended position its contents cannot be readily returned, on account of the valve-like communication, which is made tense by placing the limb in the latter position. There is also a bursa between the outer head of the gastrocnemius and the external condyle; but this is inconstant and rarely communicates with the joint.

I am indebted to Miss Rea, Mr. R. Hunter, and Mr. Samuel J. Smyth, of the Anatomical Department, Queen's University, Belfast, for the drawings which illustrate this paper, and to Major Johnston, R.A.M.C., and Captain Oldham, R.A.M.C., working in France, for the radiographs of joints injected with bismuth.

REVIEWS AND NOTICES OF BOOKS.

Practical Cystoscopy and Diagnosis of Surgical Diseases of the Kidneys and Urinary Bladder. By PAUL M. PILCHER, M.D., Consulting Surgeon to the Eastern Long Island Hospital. Large 8vo. Pp. 398, with 233 illustrations, and 29 in colours. Second edition. Philadelphia and London: W. B. Saunders Co. 25s. net.

WE congratulate Dr. Pilcher on the publication of this excellent volume on cystoscopy; the book is an artistic production, and the printing and the illustrations leave nothing to be desired; the latter are to the point and elucidate the subject matter. A slight drawback is the weight of the book, which makes it rather uncomfortable to hold.

The contents may be roughly divided into three portions: the first deals with the technique of cystoscopy, the second with the appearances seen through the cystoscope in diseased conditions of the bladder, prostate, ureter, and kidney, and the last with the therapeutic uses of the cystoscope.

In the first part the evolution of the cystoscope is sketched, and a good description of the various makes of cystoscopes given, with a full account of the physical problems involved. The author prefers the Buerger-Brown instrument, but advises the beginner not to limit himself to any one make. This is followed by a section on the technique of pyelography, which is considered by the writer to be a dangerous method of diagnosis except in the hands of expert cystoscopists. There is also a section on ureter catheterism, the best and most reasonable summary of the various methods and their respective values that we have read.

In the second part there is a full account of the various appearances in diseases of the genito-urinary organs, with numerous illustrations. If we wished to be querulous about any one point in so excellent a book, we should draw Dr. Pilcher's attention to the undesirability of adding to the terms already in use in medicine. Under the heading of cystitis, he gives no fewer than ten varieties of this condition. That these are all separate diseases seems to us improbable; it is much more likely that they represent stages in the same morbid condition. Dr. Pilcher knows this better than we do; but, as the terms at present stand, they might mislead the youthful cystoscopist. On the other hand, the chapter on the functional activity of the kidneys is quite the best we have met; it gives an impartial and reasoned critique of the methods of examination at present in use; the author concludes that these methods are of relative and not absolute value, and repeatedly insists that the results of such investigations are not of mathematical accuracy, and that, for them to be of real use, their findings must be compared with those obtained by ordinary clinical methods. On the whole he inclines decidedly to the use of the phenolsulphonephthalein test.

The chapters on the cystoscopic appearances in diseases of the kidney are among the best in the book. We draw attention specially to the diagrams of the bladder, ureter, and kidney; these show the morbid changes occurring in these organs in hydronephrosis, chronic suppurative diseases of the kidney, and in tubercle, stone, and tumour of the organ; if reproduced on a larger scale, they would be of great use in lectures to students on the subject.

In the last part the use of the high-frequency current in the treatment of tumours of the bladder is thoroughly dealt with; Dr. Pilcher is cautious in his judgement on the value of this agent, but considers it has passed the experimental stage, and that the limit of its usefulness has not yet been reached.

Dr. Pilcher is an excellent writer, and has composed a most interesting monograph on a somewhat technical subject; he steers a middle course between the unenthusiastic collector of material who places his accumulated knowledge before the reader and leaves him to extract what benefit he can, and the dogmatic enthusiast who sees only his own side of a question. He has the gift of so putting things that they stick in the memory, as when he says of boiling as the means of sterilizing ureteral catheters, "this undoubtedly shortens the life of the catheter, but it lengthens the life of the patient."

We believe that this monograph will be found on the shelves of every surgeon who is interested in cystoscopy.

Bone-graft Surgery. By FRED. H. ALBEE, M.D., Professor of Orthopædic Surgery, New York Post-Graduate School. Large 8vo. Pp. 450, with 332 illustrations, 3 in colours. London & Philadelphia: W. B. Saunders Co. 25s. net.

THERE can be no doubt that this is a really epoch-making book. If all it contains had appeared in print here for the first time it would cause a veritable sensation. For some years past we have become familiar with Professor Albee's new methods, and with his ingenious technique. In the present volume the entire subject of bone-grafting is put together in a most lucid and masterly manner, and forms such an imposing work as must greatly impress all who read it.

The opening chapter, which is one of the most valuable, gives a short and fair review of the fundamental facts relating to the transplantation and growth of bone. The periosteum is not regarded as the all-important osteogenetic tissue, but its value is nevertheless considered to be great. A bone-graft, if it be autogenous, does actually live and produce new bone, besides serving as a stimulus to osteogenesis and as an osteo-conductive medium. Although the possible use of homogenous and even heterogenous grafts, and of those kept in cold storage, is admitted, from a practical point of view the value of fresh autogenous grafts is urged. One point of great importance is made by various arguments—namely, that the living bone-graft has considerable capacity for resisting tuberculous or mild pyogenic infection, and that grafting operations will often succeed partially or wholly even in spite of a certain degree of sepsis.

The author's ingenious and compact outfit is described. He uses a small universal motor which is held in the hand, and to this various saws, twin-saws, drills, burrs, or a small dowelling tool or lathe can be attached. Great importance is laid upon the need for accurate cabinet-maker's work in bone surgery, and upon the wisdom of using electric force instead of the arm muscles for sawing bone and making holes.

The author's operation for immobilizing a tuberculous spine by means of a tibial bone-graft sewn into the split spinous processes of the vertebræ, is described in great detail, and the results in upwards of 500 cases are briefly summarized. We would suggest that an exact clinical account of 50 consecutive cases of this sort would be most welcome.

To the general surgeon, the most fascinating part of the work is the chapter devoted to the treatment of fractures. It is here that both the strength and the weakness of Albee's work appears most marked. Its strength consists in the ingenuity of device and the physiological soundness of practice in dealing with ununited fractures; its weakness, in taking too extreme a view of other operative methods and pushing his own to an unreasonable extent.

The treatment of the fractured neck of the femur by the insertion of a turned tibial peg is far in advance of any other operative procedure. But here, and in the less important case of a fractured os calcis, we think that the time and labour spent in turning the tibial peg into a cylindrical form is not only wasted but misspent. A triangular peg with rough edges can easily be driven into a circular hole made

in cancellous bone, and will grip much more tightly, whilst the turning of the bone peg must tend to devitalize it and choke up its canals with bone dust.

Albee makes himself a slave to the idea that no unabsorbable foreign body must be used in bone suture. It is true that plates and screws often cause bone absorption and tend to prevent callus formation; but it is hardly fair to represent this as the rule. According to Albee, if a broken patella or olecranon has to be operated upon, bone-grafts should be used, and the limb immobilized for four to six weeks. But by the proper use of wire of the right material and strength, these injuries can be repaired so strongly that no immobilization is wanted at all.

The possible uses of the bone-graft, and the technique of its employment, are described, with illustrative cases, in remodelling or ankylosing the hip-joint, in ankylosis of the knee, and in various other deformities, especially those where bone is congenitally absent or lost by disease.

The book, which is clearly written and well illustrated, is full of interest and instruction from the first page to the last. Its value would be greatly increased as a book of reference if a suitable bibliography had been attached.

On Modern Methods in Treating Fractures. By Ernest W. Hey Groves, M.S., M.D., B.Sc., F.R.C.S. Demy 8vo, 286 pp., with 136 illustrations. 1916. John Wright & Sons Ltd., Bristol. 7s. 6d. net.

In the early days of a new subject we hear the rival war-cries of extreme factions, each of which claims to be the sole depository of truth. Later the smoke of battle clears away, and the happy mean between opposing views is attained. In the present volume Mr. Hey Groves has assigned its approximate value to each of the methods used in the treatment of fractures. The title of the book indicates catholicity of view and a critical fairness of outlook. This impression is borne out by a perusal of the work. In his preface the author states:—

"The following small book is the outcome of several years of close experimental and clinical study of the problems of fracture treatment. It embodies the work I did on fractures in animals with the assistance of grants which were made to me by the Science Committee of the British Medical Association, and the Hunterian Lecture which I delivered in 1914. But in the present volume I have also endeavoured to examine critically the various methods of fracture treatment which are of practical importance to the modern surgeon, and to indicate the conditions in which one or another ought to be employed.

"My principal aims have been two. First, to show that the various methods of treatment should all be brought into our service as occasion requires, instead of being regarded as independent, rival, or mutually destructive systems. And, secondly, to emphasize the necessity for mechanical accuracy and efficiency in dealing with what, after all, is largely a mechanical problem.

The rest of the book represents the author's personal experiments and clinical practice, and there has been no attempt to deal with the vast literature on the subject, because this would have greatly extended the size of the book and confused its main objects set forth above.

The principles of the traditional treatment of fractures by immobilization are thus stated: (1) Setting the bone; (2) Fixing the set bone by splints or plaster; (3) Immobilizing the joints above and below the break; (4) Securing immobilization of bone and joints by tightly constricting bandages left in place until firm union has occurred; (5) Allowing the soft parts, nerves, vessels, and muscles to take care of themselves.

The author points out that, upon the evidence of *x* rays, 'setting' the bone is in most cases a myth, that consequently attempts to fix the fragments fail, that tight bandaging and prolonged fixation of the joints are most injurious to the welfare of the soft parts, and therefore to the future usefulness of the limb. Good results are frequently obtained not because of such methods, but in spite of them.

The restoration of the anatomical form of the bone is shown to be an index of the restoration of function. If the anatomical result be good, the functional result is also good in over 90 per cent of cases; if the anatomical result be moderate or bad, the functional result is good in only 29 per cent of cases.

Passing to modern methods of solving the problem, Mr. Groves groups them under three headings: (1) Methods of massage and mobilization; (2) Extension methods; (3) Operative methods.

It is clearly stated that in the presence of great deformity, massage can only be supplementary to other methods. It is pointed out that the so-called massage is a light stroking designed to relax muscular spasm and restore the patient's confidence in the possibility of movement. "If we were bold enough we ought really to call this method 'the treatment by hypnotism.'" "The criterion of efficiency and the promise of success must always be the relief and not the causation of pain. After the part has been lulled to sleep by this light stroking, the spasm of the muscles relaxes and the displacement can be reduced. The limb is then protected from injury by a bandage or splint, and this treatment is continued daily until all retentive apparatus can be discontinued. From the outset all the joints in the limb are moved after pain has been abolished, and in such a way as to cause no new pain." The range of application of the method is next discussed, and due credit is given to its pioneer, Lucas-Championnière, and to the work of Mennell in this country.

The chapters on extension methods include much that is new. Three principles are stated as cardinal in the application of extension: (1) That the main factor in the restoration and maintenance of the form of the bone is a longitudinal force pulling in the axis of the limb; (2) That this force is to be applied in such a way as not to interfere with the movements of the joints; (3) That passive and active movements of the limb should be practised from a comparatively early period, and before the extension force is removed. The different extension splints—the Balkan, the author's wire-cradle splint, the Thomas knee-splint, and the Jones abduction frame, etc.—are discussed. A special chapter is given to nail and transfixion-extension.

Perhaps Mr. Hey Groves's most valuable contribution to the treatment of fractures is his method of double transfixion combined with the use of an adjustable screw extension frame. In certain difficult fractures this ingenious method secures, at a minimum of risk, results as perfect as could be attained by open operation, and it seems assured of a permanent field of usefulness. The method may be applied in difficult cases as an auxiliary in the operative treatment of fractures, and is especially useful if skilled assistants are not present. The occasional disadvantage of sepsis at the transfixion holes is fairly recognized by the author, and doubtless may be entirely overcome in time.

The chapter which follows describes the author's experimental work on fractures artificially produced in rabbits or cats. Valuable as these researches undoubtedly are, it appears to the writer that in the treatment of human fractures they have unduly biassed the author's mind against the plating method of Lane, and in favour of treatment by intramedullary pegs or by transfixion bolts with double plates. In animal experiments it was found that with plates and screws made to the scale of those employed in human surgery the screws and plates quickly broke loose from one or both fragments. In such cases sepsis frequently supervened. No splints were employed. The results were almost uniformly unsatisfactory. It appears to the writer that Calverley's line "We're not as tabbies are" may here fairly be quoted. It is not his experience that, as our author states, removal of plates and screws by a secondary operation is frequently required, nor that in a large proportion of cases the plates become loose before firm union has taken place. The application of light splints, removable for massage, suffices usually to prevent these evils. The short Lane screw gripping one wall of the shaft of the bone does not work loose early enough to vitiate the operation in human bone unless it is subjected to undue strain. It must be admitted that the Lane method rarely forms a junction capable, even temporarily, of standing the strains to which the

normal bone is subjected. It is only intended to withstand those minimal strains resulting from involuntary muscular pull and the minor disturbances of a life in bed.

With large plates, and screws or split pins transfixing the bone, the author had better success in his experiments. Outside metal collars round the fracture were found to delay union. Steel intramedullary pegs, if loosely fitting, were found to produce excess of callus: if the peg fitted tightly, union was delayed. Nevertheless in all cases the result was successful. The author's transfixion frame gave more perfect results than any of the methods of direct operation upon the seat of fracture. To this method the author applies the term 'indirect fixation.'

Chapter VI gives an excellent account of the considerations which should guide the choice of cases for operation, and of certain points in operative technique. The author's retractor for exposing the ends of the bone appears to be an excellent device. A notable omission occurs in the section on the reduction of displacement, for there is no mention of the 'Lane manœuvre,' namely the angulation of the ends through the incision, their lodgement one upon the other, and their maintenance in contact during the subsequent alinement of the fragments. This plan is applicable unless the fracture is very oblique, and it often makes extension unnecessary.

In speaking of intramedullary pegs, the author regards them as superior to 'plating,' but nevertheless thinks their usefulness is restricted to transverse fractures of the femur, the humerus, and of both forearm bones.

The restricted field of application of the wiring method is next discussed. In this connection there are some wise remarks on the technique of wire twisting, and a useful wire-tightening forceps is described.

In the section on 'plating,' the bolted plate method is preferred. It is, however, admitted that its application involves access to the bone from two sides, and that the operation is a severe one. The importance of a drilling machine is rightly insisted on. It is indeed strange how surgeons are still content with the primitive and exhausting hand drill.

Subsequent chapters deal with the operative treatment of special fractures, and with open fractures. For ununited fractures, multiple transverse saw-cuts to open up the bone ends are advised. This appears to be an improvement on Wildey's method of drilling the ends. Bone-grafting is also discussed.

Mr. Hey Groves's book illustrates a truth which is in danger of being forgotten, namely, that the most fruitful work in surgery is done not by the pure clinician, nor by the pure pathologist, nor by the two in collaboration, but by the man who divides his time between the ward and the pathological laboratory.

Among the virtues of the book, particular attention must be drawn to its conciseness. This has not been attained at the expense of completeness of treatment. It evidently results from clear, vivid thought, from good arrangement of material, and from a desire to say what has to be said, clearly and briefly. These qualities, which are rare in medical literature, make the book a pleasure to read, and combine with the interest of the author's original work to ensure its position and influence. Emphatically it does not belong to the 'bird's nest'* class of book, and it is indispensable to every student of its subject. In a subsequent edition we hope that Mr. Hey Groves will embody his recent war experience.

Surgery in War. By Major Alfred J. Hull, R.A.M.C. With a preface by Sir Alfred Keogh, K.C.B., D.G.A.M.S. Pp. xiv + 390, with 24 plates and 55 figures. London: J. & A. Churchill. 10s. 6d. net.

This book contains a clear and concise account of the teaching and practice of war surgery by the English surgeons in the north of France. The writings of Sir Almroth Wright and of Colonel Gray have made us familiar with its main theses—

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* 'Bird's Nest'; a laborious interlacement of fragments of the work of others, adapted to the support of the author and his family.

the value of salt as a preventative of the spread of infection, and the advantages of the excision of infected wounds.

The Thomas splint is the mainstay of immobilization methods for fracture treatment. But *Fig.* 9 with its letterpress, and other remarks, prove that the claims of the chief exponent of this device have not been realized. The virtues of the Thomas splint are that the thigh ring is comfortable, and that, the leg having been over-extended and tied to the end of the splint, no further extension is necessary. But in the figure referred to, "powerful extension has been obtained by connecting the transverse bar of the splint to the tent pole with rubber tubing; this also relieves the patient of the pressure of the ring on his groin."

For the most part the book deals with the treatment of injuries within one or two days of their infliction, but in the chapters on chest injuries by Captain Miller, and on nerve injuries by Captain Snowden, a much later stage of wound treatment is considered.

The *x*-ray pictures are numerous and clear, but many of the other figures are crude. The book as a whole is a simple, clear, and valuable guide to the subject of which it treats.

The Operating Room and the Patient: a Manual of Pre- and Post-Operative Treatment. By RUSSELL S. FOWLER, M.D. Pp. 611, with 212 illustrations. Third edition. 1913. London & Philadelphia: W. B. Saunders & Co. 15s. net.

THIS book is a careful description of the practice of the author in regard to the arrangements of his operating room and the care of the patients before and after various surgical procedures. It is probably of great value for nurses and students who work with Dr. Fowler, but its value for others is limited by the fact that in so many respects it is not fully up to date. For example, spinal anæsthesia and local anæsthesia are spoken of as being performed with cocaine, and though novocain is recommended later, it seems to be a sort of after-thought. The all-important subject of shock is relegated to one short paragraph, and in this the only reference to Crile's methods occurs in the sentence, "In amputations, cocaine should be injected into the main nerve trunk of the limb."

The book contains a great quantity of valuable practical matter, which makes it useful for purposes of reference. It concludes with a tabulated list of instruments and dressings required for various operations.

The Pathology of Tumours. By E. H. KETTLE, M.D., B.S. (Lond.). Demy 8vo. Pp. viii + 224, with 126 illustrations. London: H. K. Lewis & Co. Ltd. 10s. 6d. net.

THIS book is a modest and successful attempt to give a simple and practical account of the nature and structure of tumours.

Part I deals with definitions, structure, growth, the nature of malignancy, etiology, and the experimental work of cancer research. No attempt is made to go deeply into controversial subjects, but various theories are clearly summarized. The general attitude towards all theories is that of respectful agnosticism.

Part II describes the general pathology of tumours; and in this section, as indeed throughout the book, the chief value lies in the numerous, clear, and typical microphotographs of the various conditions of which the text treats.

Part III, which treats of the special tumour growths of each tissue, is inferior to the first two, chiefly on account of its very condensed character. The figures of macroscopic specimens are not so clear as those of the microphotographs, and we think that the photographs might be replaced by drawings with great advantage.

Orthopædic Surgery. By EDWARD H. BRADFORD, M.D., and ROBERT W. LOVETT, M.D., Professors of Orthopædic Surgery, Harvard University. Pp. x + 416, with 369 figures. Fifth edition. London: Bailliere, Tindall & Cox. 15s. net.

THE fifth edition of this well-known text-book represents the changes which the authors have found it necessary to make since 1911. It has a rather larger scope than that usually implied by orthopædics in this country, inasmuch as it deals very fully with tuberculous affections of the bones and joints; on the other hand, it does not treat of the deformities due to the malunion of fractures.

All the descriptions of deformities and their treatment are full and clear, and the book represents modern orthopædic surgery very fairly, taking a *via media* between old methods of a purely retentive character and recent proposals of a more radical nature. As is proper in a text-book of this kind, such procedures as bone-grafting in spinal disease, and resection of posterior nerve roots for spastic deformities, are regarded as new methods of which the value is still uncertain.

In general terms, we would like to see less prominence given to methods of treatment by retentive apparatus made of metal and plaster, and more to physiological methods of exercises and mechanotherapy.

A New Treatment for Gonorrhœa. By CHARLES RUSS, M.B. 8vo. Pp. vii + 38. 1916. London: H. K. Lewis & Co. Ltd. 3s. net.

IN this small monograph, the author shortly reviews the commonly accepted methods of treatment of gonorrhœa, and arrives at the conclusion that they are all uncertain and inexact. He describes a method of electrolytic or ionization treatment which seems to be founded on sound scientific principles. A current of 1 to 3 milliamperes is passed for ten minutes through a catheter passed into the urethra and filled with a 2 per cent solution of sodium iodide. By this means the pus cells are drawn out from the crypts of the urethra and become attached to the electrode. From ten to twenty-two applications are necessary to cure an ordinary acute attack of gonorrhœa.

Diseases of the Nose and Throat. By SIR STCLAIR THOMSON. Pp. xvi + 858, with 22 coloured plates, and 337 figures in the text. Second edition. London: Cassell & Co. Ltd. 25s. net.

IT seems unnecessary to say much about a book which has achieved such pre-eminence during the circulation of its first edition. Its chief characteristics are its practical adaptability to clinical work, its clearness both in description and illustration, and the very valuable selection of references to the literature in all points of novelty or doubt.

It opens with a brief account of embryology, and a very practical description is given of clinical methods, in which suspension laryngoscopy now finds a place. Diseases of the nose are described in detail, except that the subject of plastic surgery is omitted and, though fractures of the nasal bones and paraffin injections are mentioned, the 'orthopædics' of the nose scarcely receives the attention it deserves. The affections of the accessory nasal sinuses are dealt with very fully, and with excellent illustrations, anatomical, radiographic, and operative. Greater stress is laid upon the intranasal drainage of frontal sinusitis than was the case in the former edition. The subject of adenoids and tonsils is described with the detail that their importance demands, and it is noteworthy that the section on removal of the tonsils has been re-written in order to emphasize the need and the methods of total enucleation as compared with the tonsillotomy which satisfied throat specialists a few years ago.

In the section on the larynx, thyrotomy is not considered to be indicated in the majority of benign tumours, because of their liability to recurrence, but on the other hand it is the operation of choice for intrinsic cancer. Gunshot wounds of the throat and larynx are not considered, although one interesting skiagram is given showing a bullet in the neck which had caused laryngeal paralysis.

The operation of intranasal dacryccystostomy, and that for the intranasal approach to the pituitary fossa, are new features of the present edition. The volume concludes with a description of the most important operations on the nose and larynx, and a list of prescriptions.

There can be no doubt that in its second edition, written on the principle of Michelet, " Un livre est toujours un moyen de faire un meilleur livre," the author has achieved his object, and produced a book of lasting value to the student, practitioner, and specialist.